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(54) **VIRTUAL REALITY MEDIA CONTENT GENERATION IN MULTI-LAYER STRUCTURE BASED ON DEPTH OF FIELD**

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G06T 7/593	(2017.01)
H04N 5/222	(2006.01)
H04N 13/117	(2018.01)
H04N 13/279	(2018.01)

(52) **U.S. Cl.**
CPC ***H04N 5/2226*** (2013.01); ***G06T 7/596*** (2017.01); ***H04N 13/117*** (2018.05); ***H04N 13/279*** (2018.05); *G02B 2027/0127* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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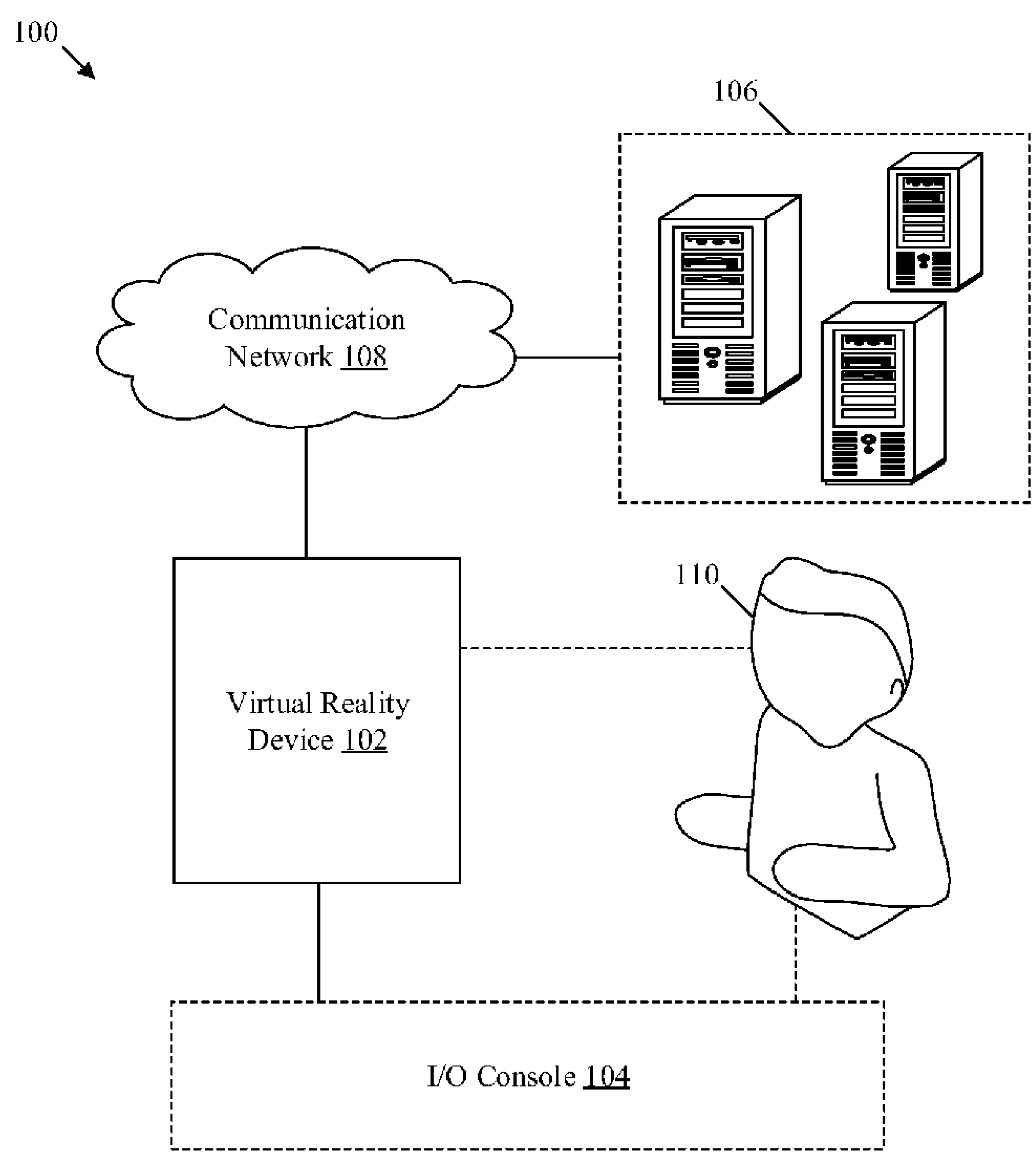
(57) **ABSTRACT**

A virtual reality (VR) device stores an encoded 360° VR video that includes a sequence of video fragments. Each video fragment includes a plurality of flat layers and each flat layer is at least one equirectangular image frame associated with an image metadata. The VR device is configured to render the plurality of flat layers in each video fragment as a plurality of concentric spherical layers projected at a plurality of depth values. The VR device is further configured to receive a plurality of user inputs associated with a modification of a set of attributes in the image metadata. The VR device is further configured to generate a modified image metadata for different concentric spherical layers and control playback of each video fragment in accordance with the modified image metadata for the different concentric spherical layer.

20 Claims, 9 Drawing Sheets



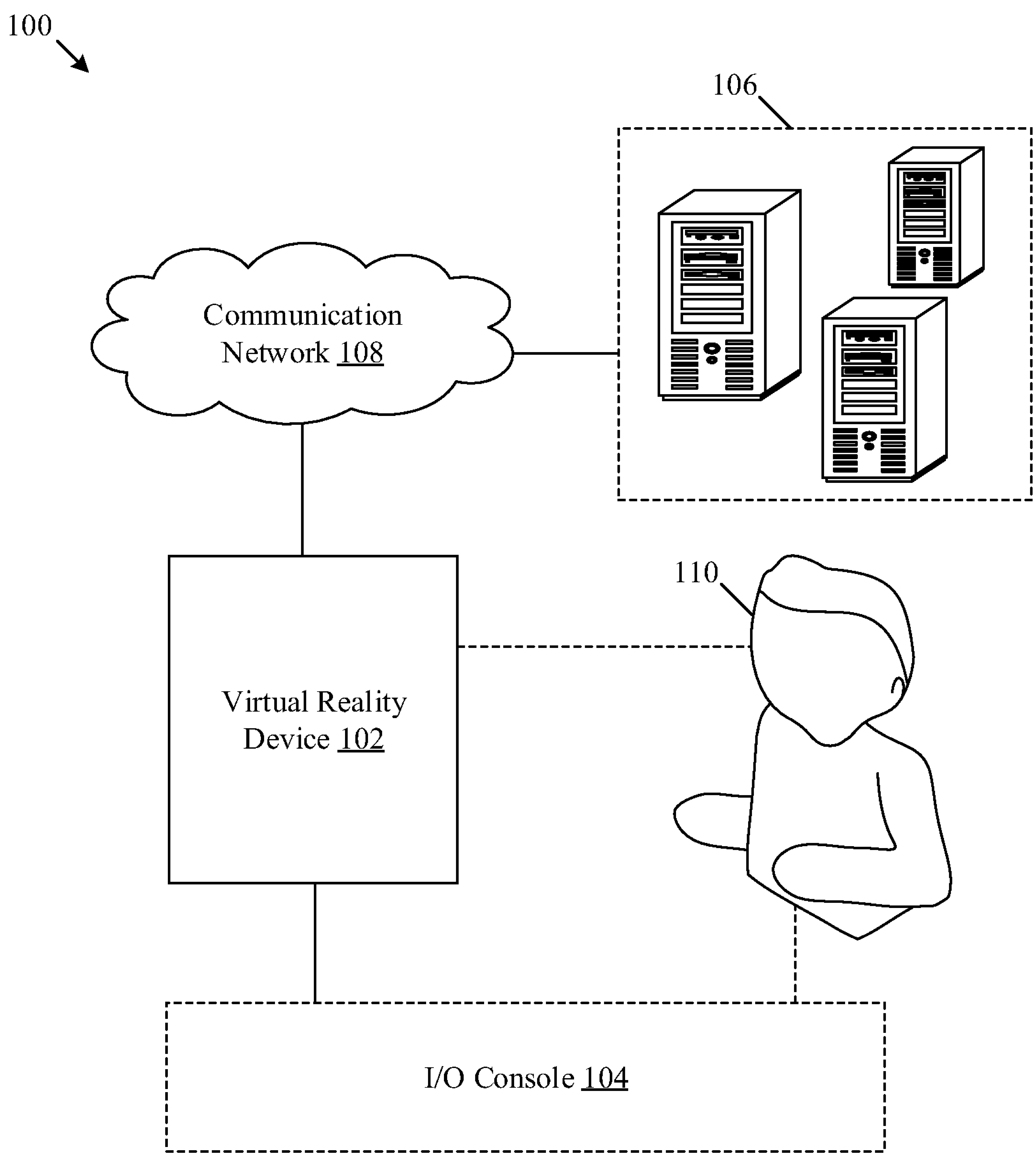

100
106
Communication
Network 108
110
Virtual Reality
Device 102
I/O Console 104

FIG. 1

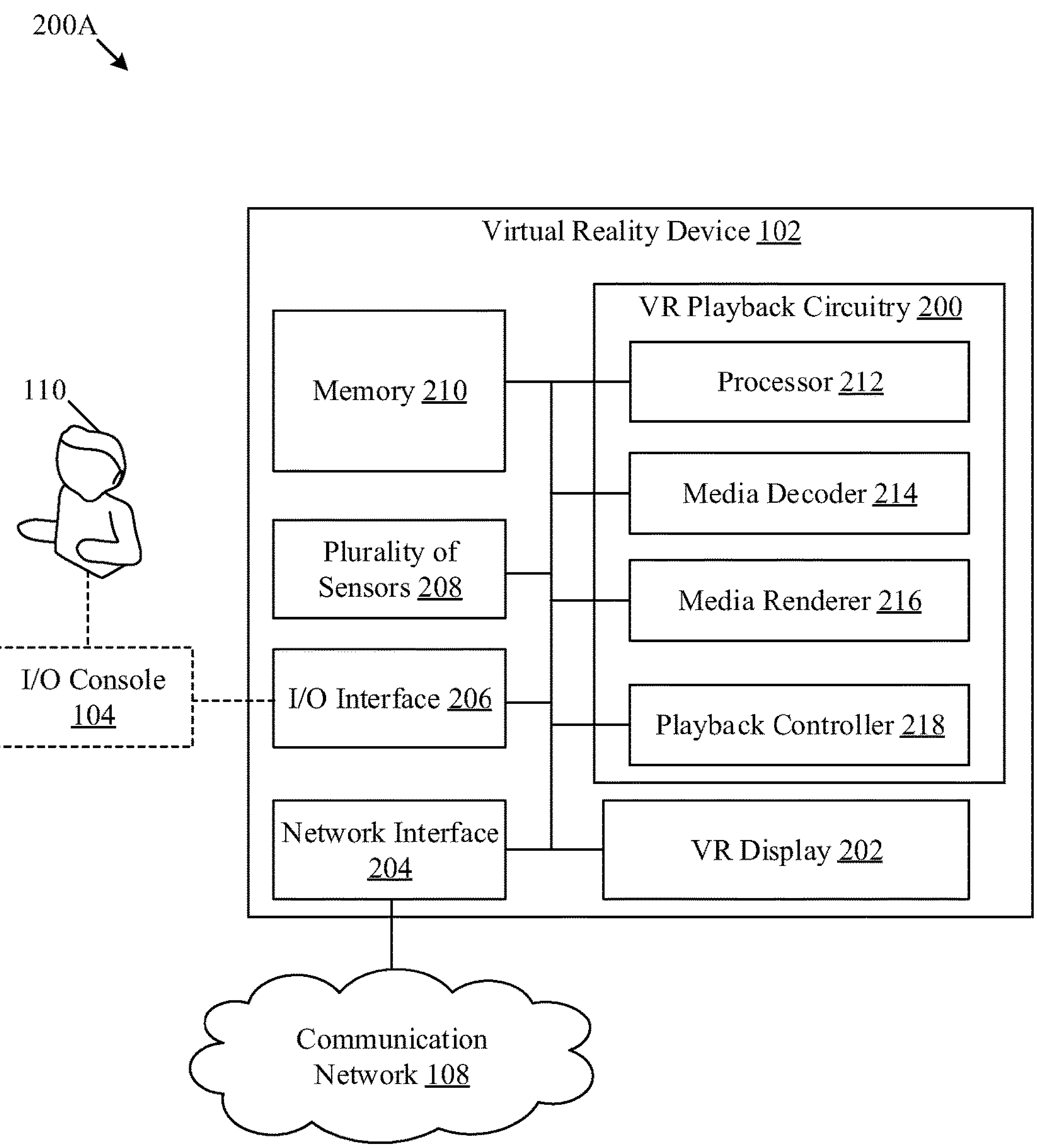

200A
110
Virtual Reality Device 102
VR Playback Circuitry 200
Memory 210
Processor 212
Media Decoder 214
Plurality of Sensors 208
Media Renderer 216
I/O Console 104
I/O Interface 206
Playback Controller 218
Network Interface 204
VR Display 202
Communication Network 108

FIG. 2A

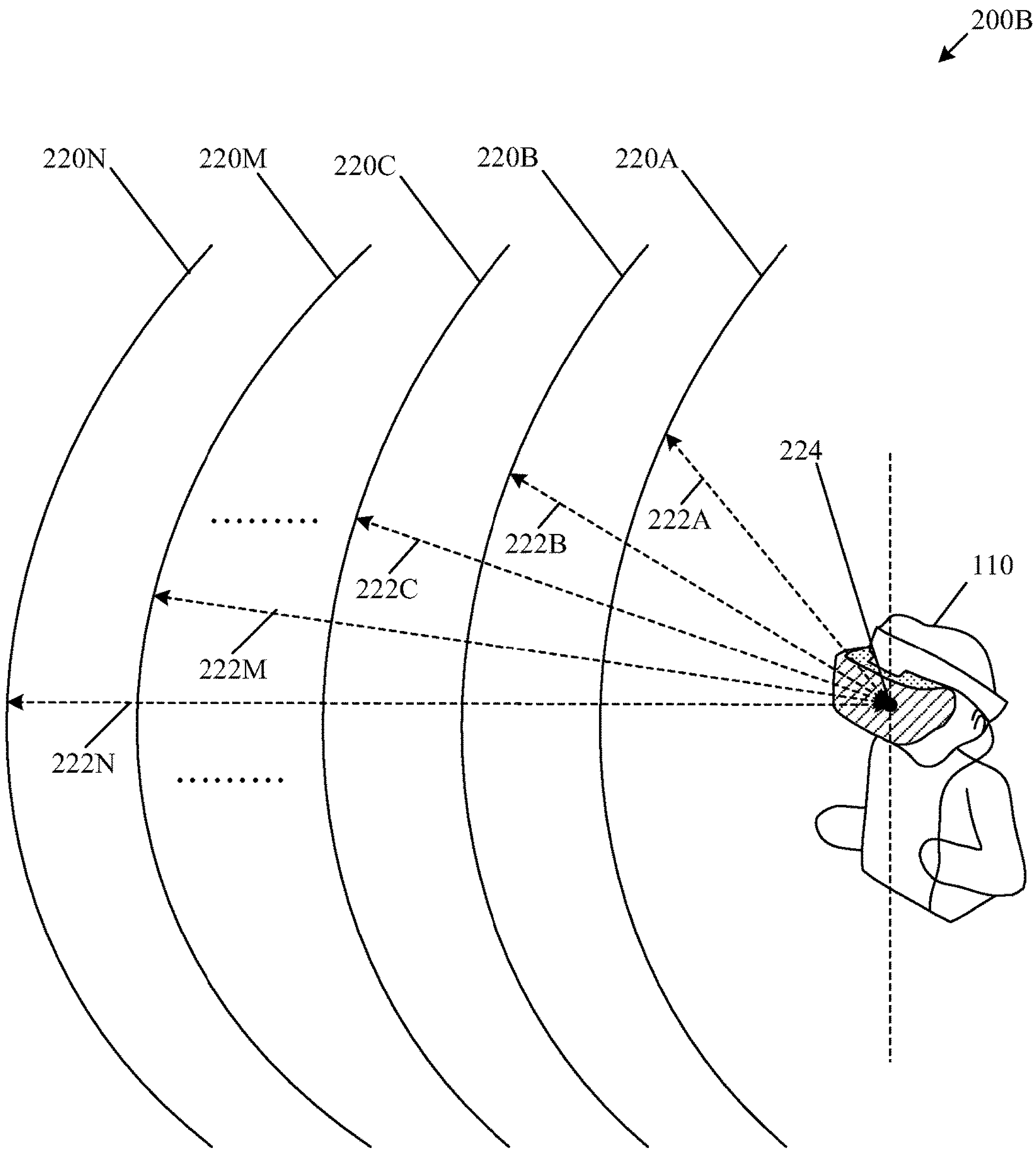

200B
220N
220M
220C
220B
220A
224
110
222A
222B
222C
222M
222N

FIG. 2B

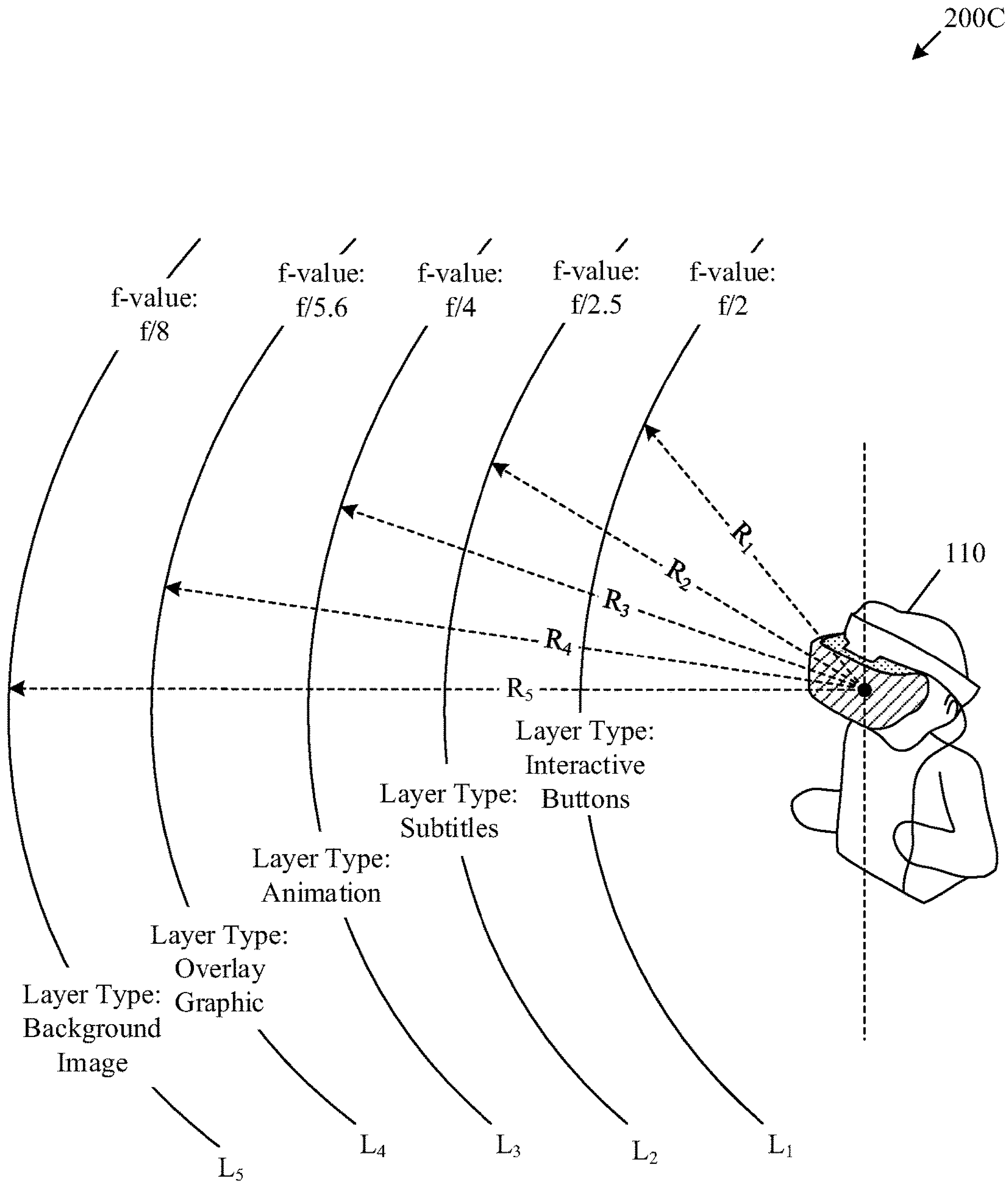

200C
f-value:
f/8
f-value:
f/5.6
f-value:
f/4
f-value:
f/2.5
f-value:
f/2
R1
R2
R3
R4
R5
110
Layer Type:
Interactive
Buttons
Layer Type:
Subtitles
Layer Type:
Animation
Layer Type:
Overlay
Graphic
Layer Type:
Background
Image
L5
L4
L3
L2
L1

FIG. 2C

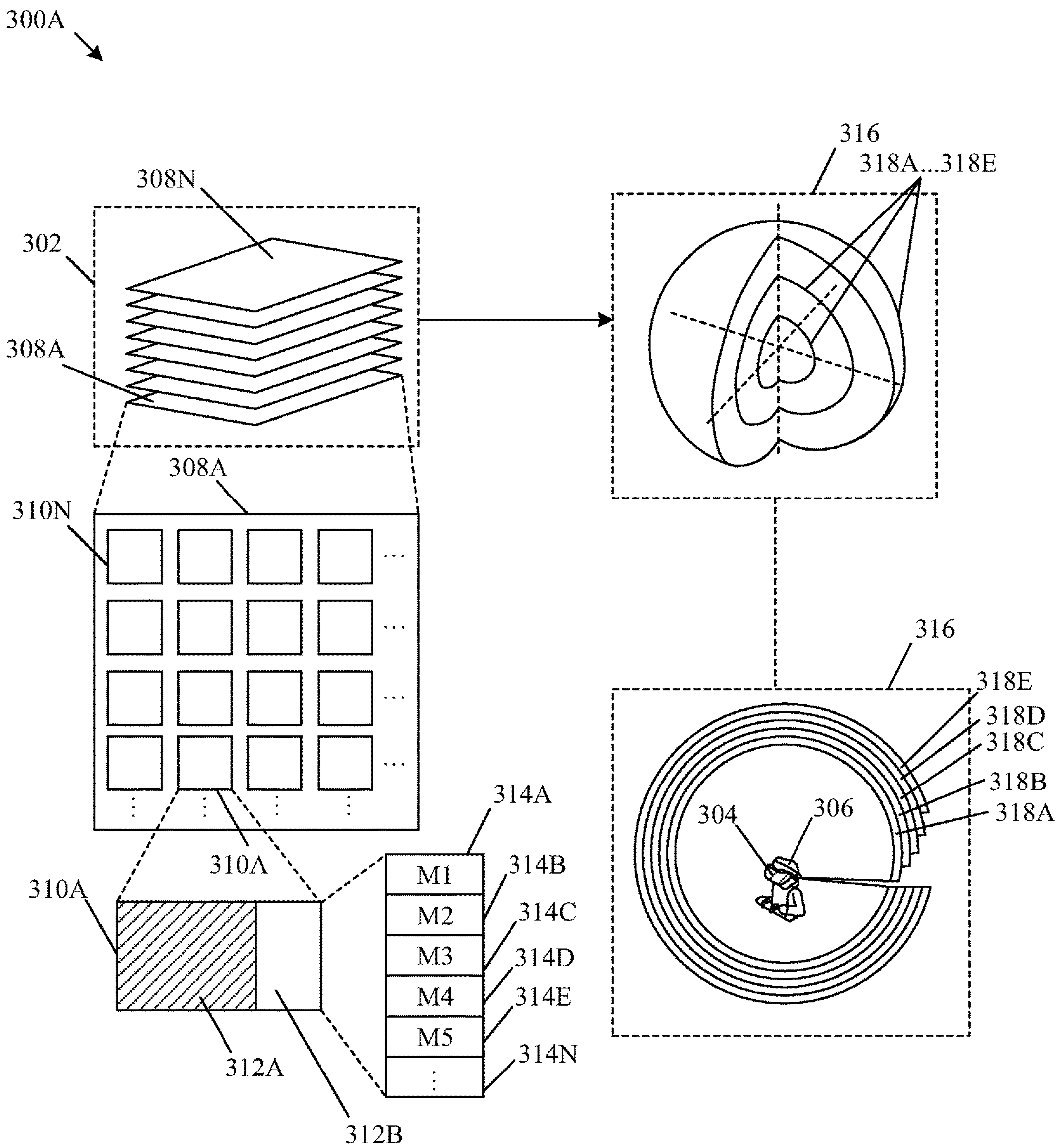

300A
302
308N
308A
308A
310N
310A
310A
312A
312B
314A
M1
M2
M3
M4
M5
314B
314C
314D
314E
314N
316
318A...318E
316
318E
318D
318C
318B
318A
304
306

FIG. 3A

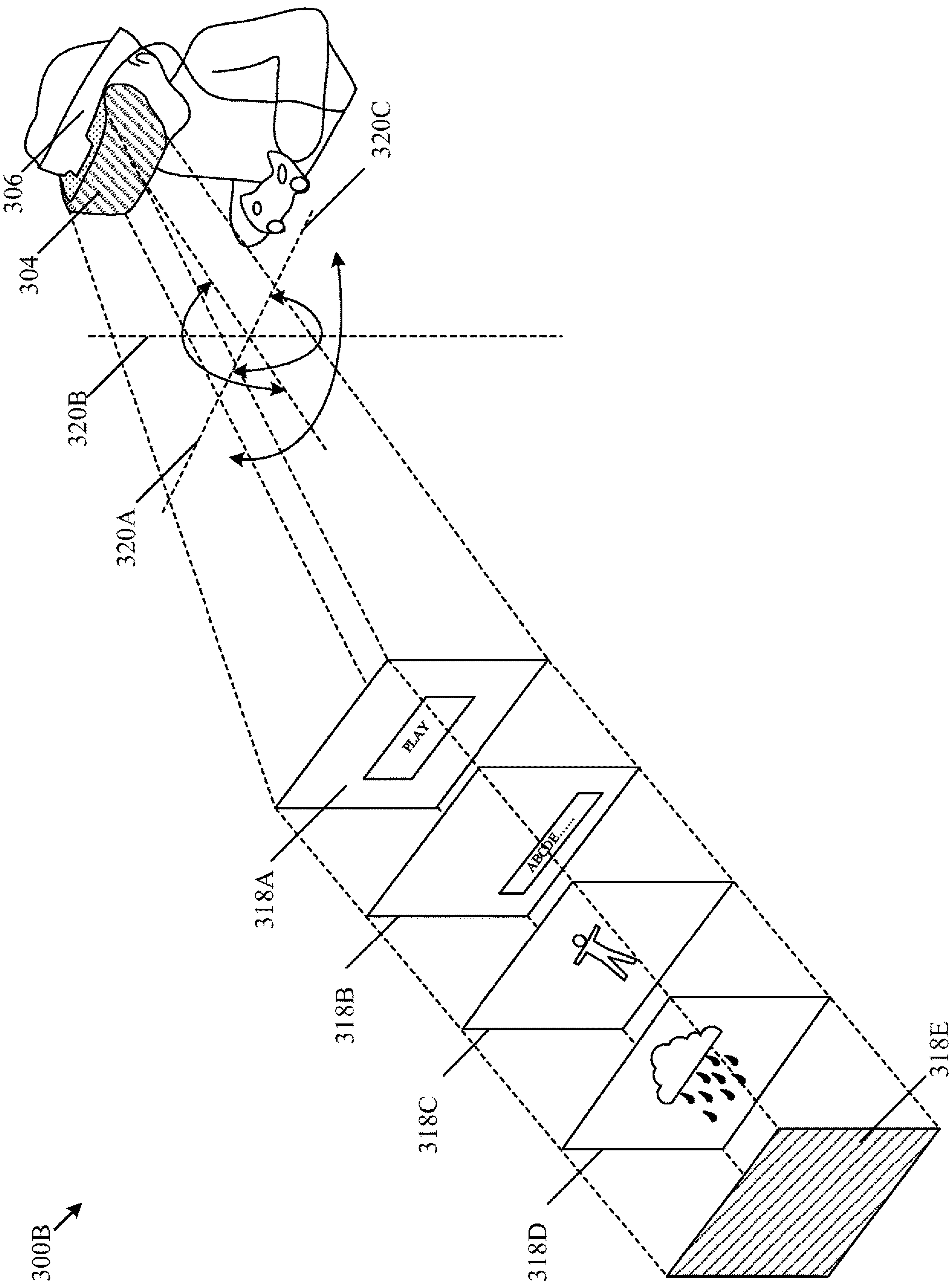

300B
306
304
320C
320B
320A
PLAY
ABCDE......
318A
318B
318C
318D
318E

FIG. 3B

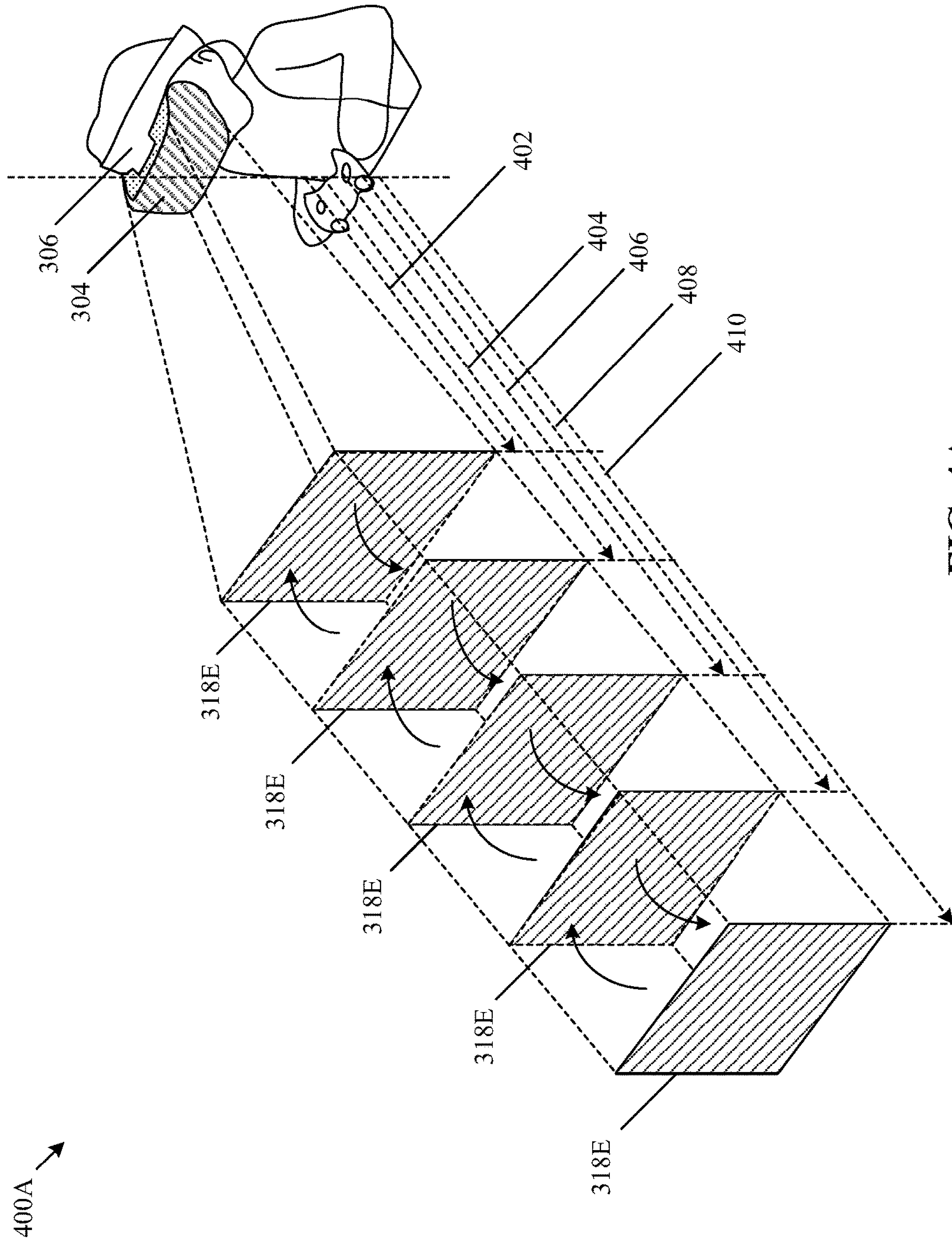


FIG. 4A

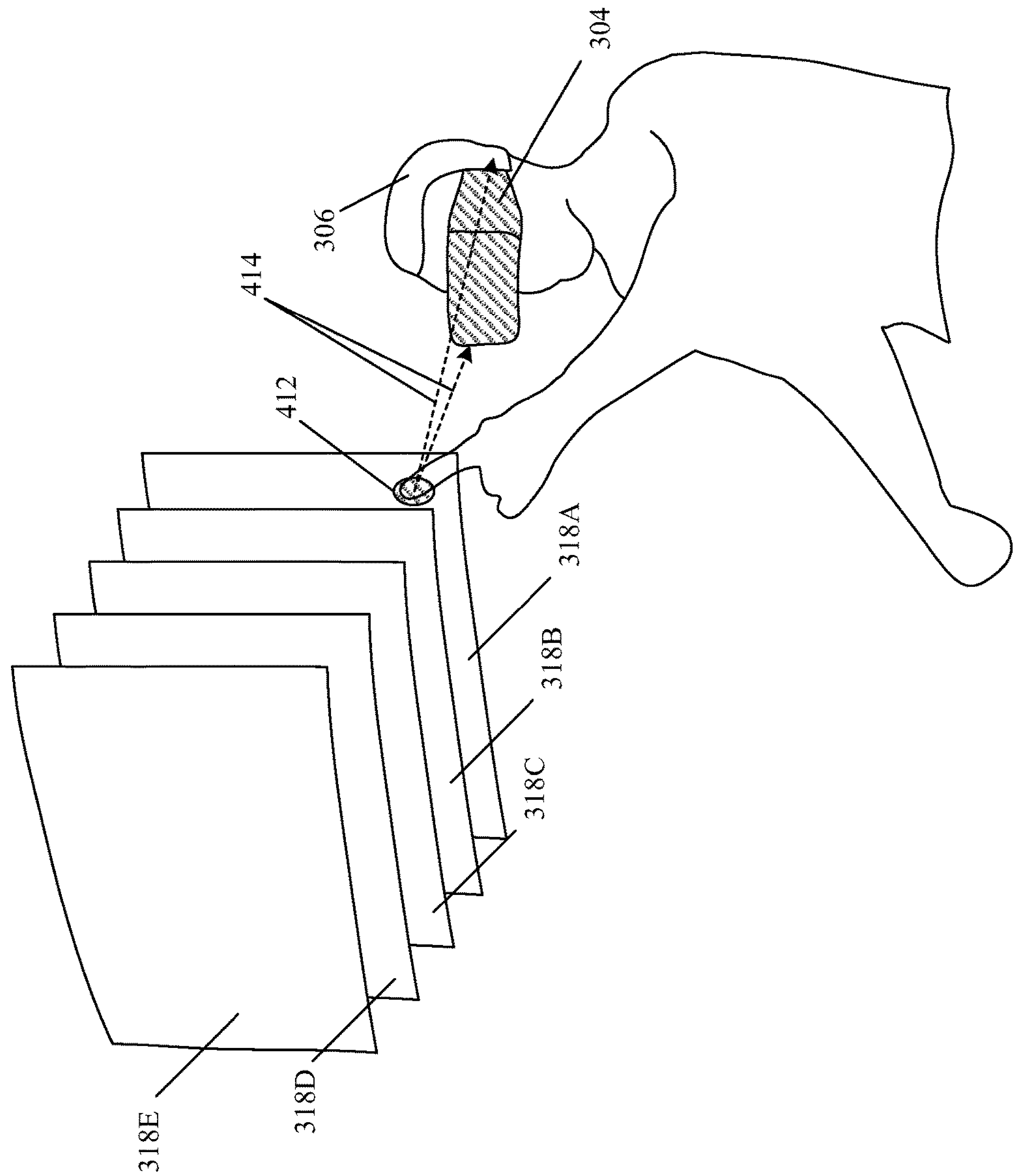


FIG. 4B

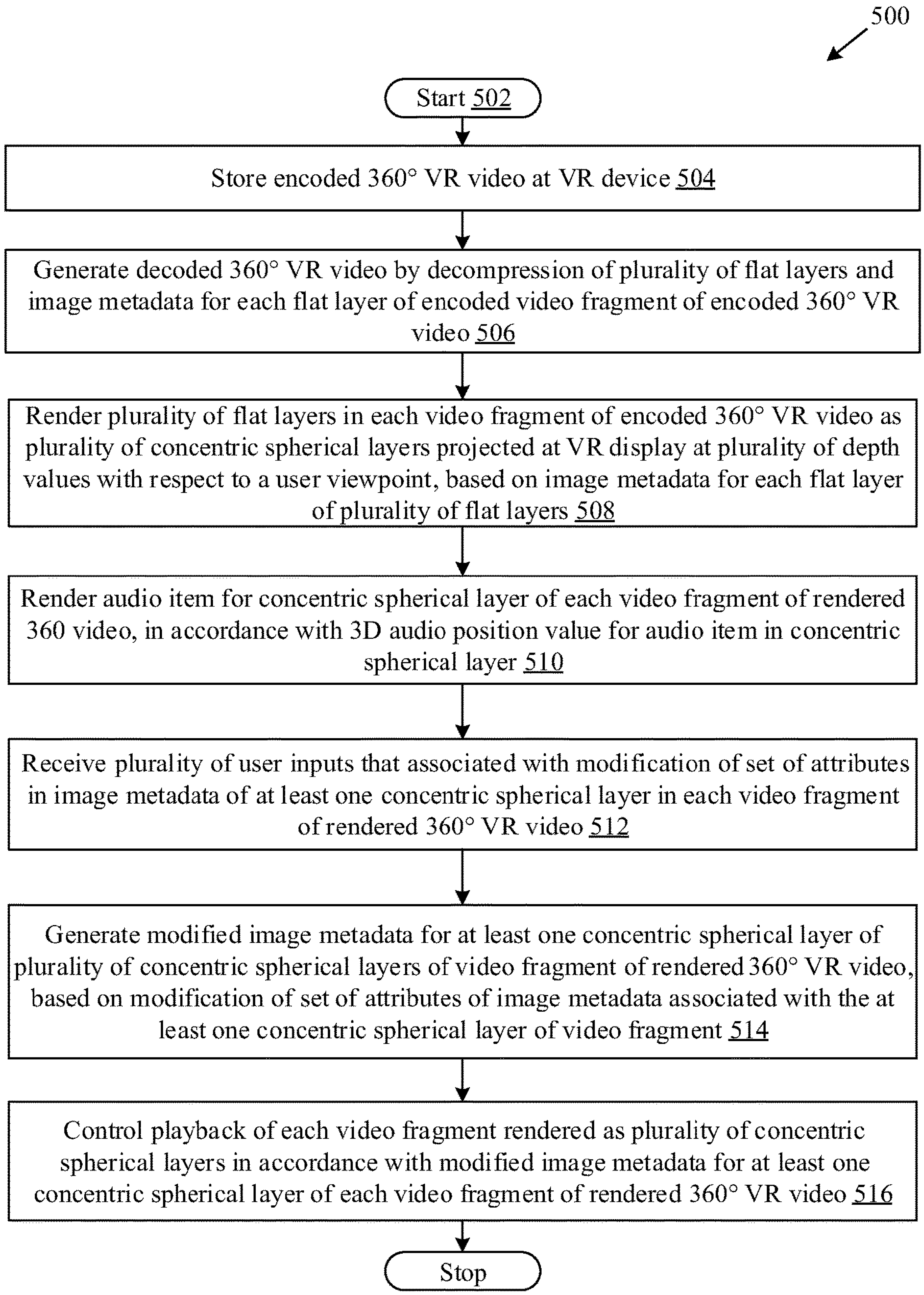

500
Start 502
Store encoded 360° VR video at VR device 504
Generate decoded 360° VR video by decompression of plurality of flat layers and image metadata for each flat layer of encoded video fragment of encoded 360° VR video 506
Render plurality of flat layers in each video fragment of encoded 360° VR video as plurality of concentric spherical layers projected at VR display at plurality of depth values with respect to a user viewpoint, based on image metadata for each flat layer of plurality of flat layers 508
Render audio item for concentric spherical layer of each video fragment of rendered 360 video, in accordance with 3D audio position value for audio item in concentric spherical layer 510
Receive plurality of user inputs that associated with modification of set of attributes in image metadata of at least one concentric spherical layer in each video fragment of rendered 360° VR video 512
Generate modified image metadata for at least one concentric spherical layer of plurality of concentric spherical layers of video fragment of rendered 360° VR video, based on modification of set of attributes of image metadata associated with the at least one concentric spherical layer of video fragment 514
Control playback of each video fragment rendered as plurality of concentric spherical layers in accordance with modified image metadata for at least one concentric spherical layer of each video fragment of rendered 360° VR video 516
Stop

FIG. 5

VIRTUAL REALITY MEDIA CONTENT GENERATION IN MULTI-LAYER STRUCTURE BASED ON DEPTH OF FIELD

CROSS-REFERENCE TO RELATED APPLICATIONS/INCORPORATION BY REFERENCE

None.

FIELD

Various embodiments of the disclosure relate to immersive virtual reality (VR) devices and technologies. More specifically, various embodiments of the disclosure relate to virtual reality media content generation in a multi-layer structure based on depth of field.

BACKGROUND

Recent advancements in the field of virtual reality (VR)-based devices have increased user engagement with VR videos on different types of VR devices, for example, VR game consoles, VR head mounted devices (HMDs), VR-based television screens, and the like. However, most of the existing 360 videos or VR videos have flat structure, in which different components, such as user interfaces (UIs), text, subtitles, computer-generated imagery (CGI), buttons, animations, and overlay graphics, are merged and overlapped into the single layer 360 video. Current video formats for 360 videos or immersive VR videos and VR rendering mechanisms limits user interactions and any change in depth values for the different components of the 360 videos or VR videos.

Further limitations and disadvantages of conventional and traditional approaches will become apparent to one skill in the art, through comparison of described systems with some aspects of the present disclosure, as set forth in the remainder of the present application and with reference to the drawings.

SUMMARY

A virtual reality (VR) device and a method for VR media content generation in a multi-layer structure based on depth of field substantially as shown in, and/or described in connection with, at least one of the figures, as set forth more completely in the claims.

These and other features and advantages of the present disclosure may be appreciated from a review of the following detailed description of the present disclosure, along with the accompanying figures in which like reference numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram that illustrates an exemplary network environment for virtual reality (VR) media content generation in a multi-layer structure and interactive playback at a virtual reality device, in accordance with an embodiment of the disclosure.

FIG. **2**A is a block diagram that illustrates an exemplary VR device for VR media content generation in a multi-layer structure and interactive playback, in accordance with an embodiment of the disclosure.

FIG. **2**B is an exemplary scenario that illustrates different rendered layers of 360° VR video at an HMD device worn by a user, in accordance with an embodiment of the disclosure.

FIG. **2**C is an exemplary scenario that illustrates different rendered layers of 360° VR video at an HMD device, in accordance with another embodiment of the disclosure.

FIG. **3**A is an exemplary scenario that illustrates a video format of a 360° VR video in a multi-layer structure that is rendered at the VR device of FIG. **2**A, in accordance with an embodiment of the disclosure.

FIG. **3**B is an exemplary scenario that illustrates a view of different rendered layers of 360° VR video at an HMD device worn by a user, in accordance with an embodiment of the disclosure.

FIG. **4**A is an exemplary scenario that illustrates a modification of a depth of field of a background layer in response to a user input, in accordance with an embodiment of the disclosure.

FIG. **4**B is an exemplary scenario that illustrates a modification of a depth of audio perception and a direction of audio perception for different rendered layers in response to a user input, in accordance with an embodiment of the disclosure.

FIG. **5** is a flow chart that illustrates an exemplary method for user-interactive playback of immersive VR video, in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION

Various embodiments of the present disclosure may be found in a method and virtual reality (VR) device for VR media content generation in a multi-layer structure and interactive playback of the generated VR media content in the multi-layer structure. The disclosed method and the VR device provides a new VR video format that is capable of packaging images/videos in a concentric 360 spherical format in a multi-layer structure. Further, the disclosed method and the VR device provides a rendering mechanism that provides an enhanced depth sense for the rendered VR media content and enables user interaction with different layers of the multi-layer structure of the rendered VR media content.

FIG. **1** is a block diagram that illustrates an exemplary network environment for virtual reality (VR) media content generation in a multi-layer structure and interactive playback at a virtual reality device, in accordance with an embodiment of the disclosure. With reference to FIG. **1**, there is shown a network environment **100** that includes a VR device **102**, and a media server **106** communicatively coupled to the VR device **102**, via a communication network **108**. In some embodiments, the VR device **102** may be communicatively coupled to an Input/output (I/O) console **104**. A user **110** may be engaged with the VR device **102** and the I/O console **104**.

The VR device **102** may comprise suitable logic, circuitry, and interfaces that may be configured to control playback of 360° VR videos in a multilayered format such that each layer is rendered at a different depth of field from a user viewpoint at the VR device **102**. The VR device **102** may include a dedicated video codec, a 3D VR display, an I/O interface, memories, a graphics accelerator or a dedicated graphical processing unit (GPU), sensor circuitries, and other computational circuitries for an offline/online playback of the 360° VR video at the VR device **102**. The VR device **102** may be implemented as a VR support system, for example, a projection-based VR support system, a wearable support system, a monitor-based VR support system, and the like. Examples of the VR device **102** may include, but are not limited to, a cave automatic virtual environment (CAVE) display system, a head-mounted display (HMD), a boom-mounted display, a fish-tank VR display, a holobench, a panoramic VR display, and a wearable VR glass.

The I/O console **104** may comprise suitable logic, circuitry, interfaces that may be configured to receive from a user (for example, the user **110**) and provide a plurality of user inputs to the VR device **102** to facilitate user-controlled interactivity with the playback of the 360° VR video at the VR device **102**. The I/O console **104** may include a plurality of input interfaces, for example, buttons and/or joysticks for stroke-based and/or movement-based inputs, gesture sensors, body posture sensors, touchscreens, and the like. Example of the I/O console **104** may include, but are not limited to, game controllers, joysticks, mouse, keyboards, depth sensors, gesture-based controllers, and the like. It may be noted that the I/O console **104** has been shown as a peripheral console device for the VR device **102**. However, the disclosure may not be so limited and the I/O console **104** or the functionalities of the I/O console **104** may be integrated into a single VR device, such as the VR device **102**, without a deviation from the scope of the disclosure.

The media server **106** may comprise suitable logic, circuitry, interfaces that may be configured to store and communicate encoded 360° VR videos to the VR device **102** for playback at the VR device **102**. The media server **106** may include suitable packages to assemble VR media content and other non-VR content (for example, subtitles, graphic items, 3D audio resources, animations, CGI, etc.) as a plurality of video fragments of the encoded 360° VR video. The media server **106** may further include audio and video codecs to encode a plurality of flat layers in each video fragment for delivery to the VR device **102**. Although not mentioned, instead of a single media server, the media server **106** may be a distributed network of media servers that share different VR content and non-VR content across different regions that may be identified by different demographic factors, for example, all the content specific to Indian users may be stored at a dedicated server for Indian users.

The communication network **108** may comprise suitable logic, circuitry, and interfaces that may be configured to provide a plurality of network ports and a plurality of communication channels for transmission and reception of data. Each network port may correspond to a virtual address (or a physical machine address) for transmission and reception of the communication data. For example, the virtual address may be an Internet Protocol Version 4 (IPV4) (or an IPV6 address) and the physical address may be a Media Access Control (MAC) address. The communication network **108** may be associated with an application layer for implementation of communication protocols based on one or more communication requests from at least one of the one or more communication devices. The communication data may be transmitted or received, via the communication protocols. Examples of the communication protocols may include, but are not limited to, HTTP (Hypertext Transfer Protocol), FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), DNS (Domain Network System) protocol, and CMIP (Common Management Interface Protocol).

In accordance with an embodiment, the communication data may be transmitted or received via at least one communication channel of the plurality of communication channels in the communication network **108**. The communication channels may include, but are not limited to, a wireless channel, a wired channel, a combination of wireless and wired channel thereof. The wireless or wired channel may be associated with a data standard which may be defined by one of a Local Area Network (LAN), a Personal Area Network (PAN), a Wireless Local Area Network (WLAN), a Wireless Sensor Network (WSN), Wireless Area Network (WAN) and Wireless Wide Area Network (WWAN). Additionally, the wired channel may be selected on the basis of a bandwidth criteria. For example, an optical fiber channel may be used for a high bandwidth communication. Further, a coaxial cable-based or Ethernet-based communication channel may be used for moderate bandwidth communication.

In operation, a user input may be received through a user interface (UI) or the I/O console **104** as a request for playback of a 360° VR video at the VR device **102**. In accordance with an embodiment, the request for the playback may be received by the media server **106** in absence of a locally stored 360° VR video in the VR device **102**. In some cases, the request may be associated with a set of user preferences for a type of content that the user **110** may intend to engage in an immersive environment. The media server **106** may be configured to package VR content overlaid with layers of non-VR content in accordance with the set of user preferences. In some implementations, the media server **106** may be configured to provide pre-packaged 360° VR video to the VR device **102**, via the communication network **108**.

In accordance with another embodiment, the VR device **102** may be configured to retrieve the 360° VR video from the VR device **102** or the media server **106**. The 360° VR video may be stored as an encoded 360° VR video at the VR device **102**. The 360° VR video may be encoded in accordance with a video format that stores the VR media content (for example, movies, CGI, or gameplay) and non-VR content (for example, overlay graphics, subtitles, or animations) as a sequence of video fragments.

The encoded 360° VR video may include a sequence of video fragments. Each video fragment of the sequence of video fragments may include a plurality of flat layers. Each flat layer of the plurality of flat layers may include at least one equirectangular image frame. Hereinafter, the at least one equirectangular image frame may be referred to as an equirectangular image frame for a single flat layer in a video fragment of the 360° VR video. Each equirectangular image frame of a flat layer may be further associated with an image metadata. The image metadata may include layer information associated with a layer type, a depth value, a three dimensional (3D) audio position value, an alpha value, and media player-specific information. Such layer information may be further utilized to render different flat layers of 360° VR video at the VR device **102**.

The VR device **102** may be configured to generate a decoded 360° VR video by decompression of the plurality of flat layers and the image metadata for each flat layer of each encoded video fragment of the encoded 360° VR video. The VR device **102** may be configured to render the plurality of flat layers in each video fragment of the encoded 360° VR video at the VR device **102**. The plurality of flat layers may be rendered as a plurality of concentric spherical layers that may be projected by the VR device **102** at a plurality of depth values with respect to a user viewpoint (as shown in FIG. **3**A and FIG. **3**B). A specification to compute rendered models for the plurality of flat layers may be provided in the image metadata for each flat layer of the plurality of flat layers.

In accordance with an embodiment, the decoded 360° VR video may be rendered differently in accordance with a type of VR environment that is rendered for the user **110** (or a group of users). The type of VR environment may include a fully immersive VR environment and a partially immersive VR environment. For example, the fully immersive environment may correspond to a scenario where the 360° VR video is rendered on the VR device **102** such that a user wearing the VR device **102** may experience a self-deportation into an immersive and interactive VR environment created through rendering of the 360° VR video. The self-deportation experience may also be referred to as a first person view of the VR environment, where the user **110** may directly engage with different components of the VR environment. The partially immersive VR environment may correspond to a scenario where the 360° VR video is rendered on the VR device **102** such that a user wearing the VR device **102** may experience a guided and/or instructed engagement into an immersive and interactive VR environment created through rendering of the 360° VR video. The guided and/or instructed engagement may also be referred to as a second or a third person view of the VR environment, where the user **110** may passively engage with different components of the rendered VR environment.

The type of VR environment may further depend on at least a field-of-view for a scene at the VR device **102** with respect to the user viewpoint. The field-of-view may vary with different types of VR devices in use by the user **110**. For example, a field of view for a 3D computer monitors, HMDs/Boom-Displays, Holobenches, wall mounted displays, panoramic displays, and six-sided caves, has been known to lie in a range of "20°-40°", "30°-80°", "80°-120°", "100°-140°", "160°-180°", and up to "360°", respectively. Therefore, HMDs, Boom-displays, and six-sided caves may be utilized as the VR device **102** to provide a fully immersive environment to the user **110**, for the rendered 360° VR video. On the contrary, the 3D computer monitors, the Holobenches, the panoramic screens and "3-5" sided caves may be utilized as the VR device **102** to provide a partially immersive environment to the user **110**, for the rendered 360° VR video.

In accordance with an embodiment, the VR device **102** may be further configured to modify different attributes associated with the rendered 360° VR video. The different attributes associated with the rendered 360° VR video are specified in the image metadata for each layer of the rendered 360° VR video. The different attributes associated with the rendered 360° VR video are modified in response to user input at the time of viewing of the rendered 360° VR video. Such modification in the different attributes associated with the rendered 360° VR video provides an interactivity with the different elements viewed at different depth (i.e. depth of field from user's viewpoint) in the rendered 360° VR video. Further, such modifications may be done to personalize the immersive experience for the user **110** with the playback of the 360° VR video at the VR device **102**.

The VR device **102** may be further configured to receive a plurality of user inputs. The plurality of user inputs may be associated with a modification of a set of attributes in the image metadata associated with at least one concentric spherical layer of the plurality of concentric spherical layers in each video fragment of the rendered 360° VR video at the VR device **102**. Hereinafter, the at least one concentric spherical layer may be referred to as user-selected concentric spherical layers. The VR device **102** may be configured to generate a modified image metadata for the user-selected concentric spherical layer of the plurality of concentric spherical layers in each video fragment of the rendered 360° VR video. The modified image metadata for the user-selected concentric spherical layers may be generated based on modification of the set of attributes of the image metadata associated with the user-selected concentric spherical layers of each video fragment of the rendered 360° VR video.

The VR device **102** may be configured to utilize the modified image metadata to re-render the user-selected concentric spherical layers at the VR device **102**. Alternatively stated, the VR device **102** may be configured to control playback of each video fragment rendered as the plurality of concentric spherical layers. The playback may be controlled in accordance with the modified image metadata for the user-selected concentric spherical layers of each video fragment of the rendered 360° VR video. The playback of each video fragment may be controlled based on a user-selection of the set of attributes in the image metadata. In some embodiments, the controlled playback of each video fragment in accordance with the modified image metadata may correspond to at least one of a switch in a position, a modification of content, a modification of an audio depth perception and a direction of audio perception, or a level of transparency of different concentric spherical layers of each video fragment in the rendered 360° VR video.

In accordance with an embodiment, the encoded 360° VR video may exhibit a modularity associated with a degree by which different components of the encoded 360° VR video may be separated, recombined, or modified at the VR device **102**. Thus, as a result of modularity in data structure/video format of an encoded 360° VR video, the media server **106** may broadcast a media stream of the encoded 360° VR video in accordance with targeted requirements for different types of users. Such types of users may be further identified based on different demographic factors, for example, region, religion, race, age group, gender, native language, financial conditions, and the like. For example, the content of text layer may vary (e.g. Japanese Subtitles, English Subtitles, Hindi Subtitles, etc.) in different broadcasted media stream of the encoded 360° VR video in accordance with a native language of the users that may watch the 360° VR video.

FIG. **2**A is a block diagram that illustrates an exemplary VR device for VR media content generation in a multi-layer structure and interactive playback, in accordance with an embodiment of the disclosure. FIG. **2**A is explained in conjunction with elements from FIG. **1**. With reference to FIG. **2**A, there is shown a block diagram **200**A of the VR device **102**. The VR device **102** may include VR playback circuitry **200**, a VR display **202**, a network interface **204**, an input/output (I/O) interface **206**, a plurality of sensors **208**, and a memory **210**. The VR playback circuitry **200** may further include a processor **212**, a media decoder **214**, a media renderer **216**, and a playback controller **218**. Although not shown, the VR device **102** may further include other circuitries, for example, speakers, graphic accelerators, power circuits, and the like.

The VR display **202** may comprise suitable logic, circuitry, and interfaces that may be configured to display an immersive virtual environment that includes a spherical projection of a 360° VR video that is layered into multiple concentric layers. The VR display **202** may be a 3D VR screen that may display a rendered 360° VR video at an adjustable depth of field. Such 3D VR screen may be categorized based on a type of VR device **102**, for example, a projection-based VR display, a wearable VR display, and an external VR display monitor. Examples of the VR display **202** may include curved display screens in HMDs and panoramic devices, flat display screens in HMDs, panoramic devices, boom-display devices, flat monitors, and the like. In accordance with an embodiment, the VR display **202** may be further realized through several known technologies such as, but not limited to, at least one of a Liquid Crystal Display

(LCD) display, a Light Emitting Diode (LED) display, a plasma display, and an Organic LED (OLED) display technology, and other display resources. The VR display **202** may refer to a display screen of a smart-glass device, a see-through display, a projection-based display, an electrochromic display, and a transparent display, and the like.

The network interface **204** may comprise suitable logic, circuitry, and interfaces that may be configured to communicate with other systems and devices, via the communication network **108**. The network interface **204** may be implemented by use of known technologies to support wired or wireless communication of the VR device **102** with the communication network **108**. Components of the network interface **204** may include, but are not limited to, an antenna, a radio frequency (RF) transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a coder-decoder (CODEC) chipset, a subscriber identity module (SIM) card, and/or a local buffer circuit.

The I/O interface **206** may comprise suitable logic, circuitry, and interfaces that may be configured to operate as an I/O channel/interface between the user **110** and the different operational components of the VR device **102**. The I/O interface **206** may facilitate an I/O device (for example, the I/O console **104**) to receive an input from the user **110** and present an output based on the provided input from the user **110**. The I/O interface **206** may include various input and output ports to connect various I/O devices that may communicate with different operational components of the VR device **102**. Examples of the input devices may include, but is not limited to, a touch screen, a keyboard, a mouse, a joystick, a microphone, and an image-capture device. Examples of the output devices may include, but is not limited to, a display (for example, the VR display **202**), a speaker, and a haptic or other sensory output devices.

The plurality of sensors **208** may comprise suitable logic, circuitry, and interfaces that may be configured to collect and store information associated with the user **110** and a plurality of ambient parameters that may affect an immersive experience of the user **110**. The plurality of sensors **208** may be implemented as embedded/wearable sensors with the VR device **102**. In other embodiments, the plurality of sensors **208** may be implemented as part of a distributed sensory environment, where a portion of the sensors implemented as embedded/wearable sensors with the VR device **102** and a remnant portion of the sensors are implemented in the ambient environment of the user **110**. Examples of the plurality of sensors **208** may include, but are not limited to, image sensors, microphones, gyroscopes, accelerometers, proximity sensors, magnetometers, touch sensors, luminance sensors, and other micro-electromechanical systems (MEMS) sensors or nano-electromechanical systems (NENS) sensors. For example, an HMD VR device may implement a combination of different MEMS-gyroscope sensors to detect six degrees of freedom with respect to different possible head movements along axes (such as yaw axis, roll axis, and pitch axis) associated with the HMD VR device.

The memory **210** may comprise suitable logic, circuitry, and interfaces that may be configured to store a set of instructions executable by the processor **212**, the media decoder **214**, the media renderer **216**, and the playback controller **218**. The memory **210** may be configured to store encoded 360° VR video and decoded 360° VR video. The memory **210** may be further configured to store the image metadata and user preference data for different layers of each video fragment of the 360° VR video. Examples of implementation of the memory **210** may include, but are not limited to, Random Access Memory (RAM), Read Only Memory (ROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), Hard Disk Drive (HDD), a Solid-State Drive (SSD), a Central Processing Unit (CPU) cache, and/or a Secure Digital (SD) card.

The processor **212** may comprise suitable logic, circuitry, and interfaces that may be configured to execute a set of instructions stored in the memory **210**. The processor **212** may be implemented based on a number of processor technologies known in the art. Examples of the processor **212** may include, but are not limited to, a Graphical Processing Unit (GPU), a CPU, an x86-based processor, an x64-based processor, a Reduced Instruction Set Computing (RISC) processor, an Application-Specific Integrated Circuit (ASIC) processor, a Complex Instruction Set Computing (CISC) processor.

The media decoder **214** may comprise suitable logic, circuitry, and interfaces that may be configured to generate a decoded 360° VR video by decompression of the plurality of layers in encoded video fragments of the encoded 360° VR video. In some embodiments, the media decoder **214** may be implemented as a specialized hardware decoder interfaced with the other computational circuitries of the VR device **102**. In such implementation, the media decoder **214** may be associated with a specific form factor on a specific computational circuitry. Examples of the specific computational circuitry may include, but are not limited to, a field programmable gate array (FPGA), programmable logic devices (PLDs), an application specific integrated circuit (ASIC), a programmable ASIC (PL-ASIC), application specific integrated parts (ASSPs), and a System-on-Chip (SOC) based on standard microprocessors (MPUs) or digital signal processors (DSPs). In other embodiments, the media decoder **214** may be further interfaced with a graphical processing unit (GPU) to parallelize operations of the media decoder **214**. Additionally, the media decoder **214** may be implemented as a combination of programmable instructions stored in the memory **210** and logical units (or programmable logic units) on a hardware circuitry in the VR device **102**.

The media renderer **216** may comprise suitable logic, circuitry, and interfaces that may be configured to render the plurality of flat layers in the decoded 360° VR video as a plurality concentric spherical layers such that the plurality concentric spherical layers are projected at a plurality of depth values at the VR display **202** of the VR device **102**. Such plurality of depth values may facilitate the user **110** to visualize different concentric layers at different depth of fields. In some embodiments, the media renderer **216** may be implemented as a hardware media render circuitry at the VR device **102** that utilizes computational resources of the memory **210** and the processor **212**. In other embodiments, the media renderer **216** may be further interfaced with a graphical processing unit (GPU) to parallelize operations of the media renderer **216**. Additionally, the media renderer **216** may be implemented as a combination of programmable instructions stored in the memory **210** and logical units (or programmable logic units) on a hardware circuitry in the VR device **102**.

The playback controller **218** may comprise suitable logic, circuitry and interfaces that may be configured to control the playback of the rendered 360° VR video at the VR display **202** of the VR device **102** based on a plurality of user inputs provided by the user **110**. The controlled playback of the rendered 360° VR video may be associated with modifications of at least one of layer content, a depth of field of different layers, a depth of audio perception, a layer transparency, and the like. In some embodiments, the playback controller **218** may be implemented as a hardware media render circuitry at the VR device **102** that utilizes computational resources of the memory **210** and the processor **212**. In other embodiments, the playback controller **218** may be further interfaced with a graphical processing unit (GPU) to parallelize operations of the playback controller **218**. Additionally, the playback controller **218** may be implemented as a combination of programmable instructions stored in the memory **210** and logical units (or programmable logic units) on a hardware circuitry in the VR device **102**. In some embodiments, the playback controller **218** may be integrated with the media renderer **216** as a single operational circuitry in the VR device **102**, without a deviation from scope of the disclosure.

In operation, different components of the VR playback circuitry **200** at the VR device **102** may receive a playback request from the I/O interface **206**. The playback request may be initiated by the user **110** (or a group of users) for playback of an encoded 360° VR video at the VR display **202**. In one implementation, the playback request may be received at the network interface **204**, via the communication network **108**. In another implementation, instead of the network interface **204**, the playback request may be received directly at the I/O interface **206**. In response to the playback request, the processor **212** may be configured to identify the VR media content (in the form of an encoded 360° VR video) that the user **110** intends to watch or engage with, at the VR device **102**.

The memory **210** may be configured to retrieve the encoded 360° VR video that matches a user preference of the playback request. The encoded 360° VR video may include a sequence of video fragments. Each video fragment of the sequence of video fragments may include a plurality of flat layers. Each flat layer of the plurality of flat layers may include at least one equirectangular image frame that is associated with an image metadata. Each video fragment of the sequence of video fragments may be further stored in a dedicated allocation in the memory **210** of the VR device **102** in accordance with a specific data structure. The specific data structure (or format) may indicate a way different VR content and non-VR content in each fragment may be accessed from the memory **210** at the VR device **102** (as illustrated in FIG. **3**A). The media decoder **214** may be configured to decompress the plurality of flat layers and the image metadata for each flat layer of the encoded video fragment of the encoded 360° VR video. The media decoder **214** may generate a decoded 360° VR video after the decompression of different layers of the encoded 360° VR video. The decoded 360° VR video may be further processed for playback at the VR device **102**. The detailed operation for the playback of the decoded 360° VR video has been further described in FIG. **2**B, in detail.

FIG. **2**B is an exemplary scenario that illustrates different rendered layers of 360° VR video at an HMD device worn by a user, in accordance with an embodiment of the disclosure. FIG. **2**B is explained in conjunction with elements from FIGS. **1** and **2**A. With reference to FIG. **2**B, there is shown a scenario **200**B where a user (for example, the user **110**) who wears an HMD device engages with the rendered 360° VR video.

The media renderer **216** may be configured to render the plurality of flat layers in each video fragment of the encoded 360° VR video as a plurality of concentric spherical layers **220**A . . . **220**N projected at the VR display **202**. Each flat layer may represent an equirectangular projection of a 2D image frame on a rectilinear plane (or a gnomonic projection) and each concentric spherical layer (for example, a spherical layer **220**A) may represent a spherical projection of the same 2D image on a spherical plane. Thus, the media renderer **216** may be configured to transform a projection of a 2D image frame from an equirectangular plane to a spherical plane at the VR display **202** of the VR device **102**. The user **110** at the center of the spherical plane may see a rectilinear projection of the same 2D image within a given field-of-view of the user **110**. The plurality of concentric spherical layers **220**A . . . **220**N may be projected at a plurality of depth values **222**A . . . **222**N with respect to a user viewpoint **224**. A depth value for each flat layer of each video fragment may correspond to a radius of a concentric spherical layer measured with respect to the user viewpoint **224**. Alternatively stated, the plurality of concentric spherical layers **220**A . . . **220**N may be rendered such that the user viewpoint **224** lies at the center of the plurality of concentric spherical layers **220**A . . . **220**N. Thus, each concentric spherical layer may provide an immersive depth of field that increases with an increase in radius of such concentric spherical layer at the VR display **202**. Each of the plurality of concentric spherical layers **220**A to **220**N may be associated with a depth of field that may be represented by a difference between depth values of two consecutive concentric spherical layers. The depth of field may also refer to a resolution of content displayed in a concentric spherical layer in a longitudinal plane. The depth of field may be represented by a distance from a nearest object plane in focus to a farthest object plane that may be simultaneously in focus in different concentric spherical layers, whereas the depth value may represent a radius of each concentric spherical layer with respect to user's viewpoint. In some embodiments, the depth of field for each concentric spherical layer may be controlled, by the VR device **102**, based on a change in an f-number or a focal length of an imaging device that captures an image rendered as a spherical concentric layer. The f-number may be represented by N, which is also represented as a ratio "f/D", where "f" is the focal length of the lens used by an imaging device and "D" is a diameter of lens aperture exposed to light. The depth of field (D_F) may be represented by an equation (1), as follows:

$$D_F=2\times N\times C\times d^2/f^2 \tag{1}$$

Where, C represents a circle of confusion, and d represents a distance between the lens and a reference object (i.e. the user **110**).

The circle of confusion (c) may represent a blur spot diameter at a particular point in an image (rendered as a concentric spherical layer) which further represents an acceptable depth of field or sharpness of objects depicted in the image at the particular point. The plurality of concentric spherical layers **220**A to **220**N may be rendered based on the image metadata for each flat layer of the plurality of flat layers. Alternatively stated, the media renderer **216** may utilize a set of attributes specified in the image metadata for each flat layer of the plurality of flat layers in the sequence of video fragments. The set of attributes specified in the image metadata may include layer information associated with a layer type, a depth value, a three dimensional (3D) audio position value, an alpha value, and media player-specific information.

The decoded 360° VR video may be rendered as the plurality of concentric spherical layers **220**A to **220**N to assign a different depths of field to each concentric layer at the VR device **102**, as compared to conventionally rendered flat 360° VR videos that are rendered on a single sphere of a fixed radius and lack a perception of a depth of field for different layers in a scene. This is advantageous as assigning a different depth of field to each concentric layer at the VR device **102** provides an enhanced depth sense for different layers in the scene.

In some embodiments, the plurality of concentric spherical layers **220**A to **220**N may include a background spherical layer **220**N and a plurality of spherical item layers **220**A . . . **220**M. The media renderer **216** may be configured to render the background spherical layer **220**N as an outermost concentric spherical layer of the plurality of concentric spherical layers **220**A to **220**N. The background spherical layer **220**N may be associated with a depth value that is a maximum of the plurality of depth values **222**A . . . **222**N specified for the plurality of flat layers in each video fragment of the decoded 360° VR video. Accordingly, the media renderer **216** may be further configured to render each of the plurality of spherical item layers as an inner concentric spherical layer of the plurality of concentric spherical layers **220**A to **220**N. Alternatively stated, in some implementations, the background spherical layer **220**N may be focused at a maximum depth value (i.e. a maximum radius of concentric spherical layer) at the VR display **202** of the VR device **102** and the plurality of spherical item layers **220**A . . . **220**M may be rendered at a low depth values (i.e., a lower radius of concentric spherical layers) of field with respect to the depth of field of the background spherical layer **220**N. In some implementations, the background spherical layer **220**N may include an image frame associated with the requested VR media content and the plurality of spherical item layers **220**A . . . **220**M may include at least one of a graphic image, textual content, an interactive button, a user interface, a 3D depth texture, a computer-generated imagery (CGI), or an animation sequence. Alternatively stated, the plurality of spherical item layers may be utilized as additional layers (for example, subtitles, animation effects, and overlay graphics (such as ads, player information, report card, and the like)) that supplement the VR media content of the background layer.

For example, a rendered 360° VR video of a gameplay for a virtual football match may include a sequence of video fragments (F_1 . . . F_N). Of the sequence of video fragments (F_1 . . . F_N), a first video fragment (F_1) may include a plurality of concentric spherical layer (L_1 . . . L_N) rendered at the VR display **202** of the VR device **102**. The first concentric spherical layer (L_1) may be an innermost spherical item layer (e.g., a graphical button that is rendered nearest to a user's viewpoint) and the other concentric spherical layers (L_2 . . . L_{N-1}) may be the plurality of spherical item layers that may be rendered at depth values that is more than a depth value for a background spherical layer (L_N). In case of a five layered VR football match, the first spherical layer (L_1) may project a view of a playground within a stadium filled with virtual audiences at a minimum depth value (i.e., minimum radius). A second spherical layer (L_2) may project an overlay graphic of players in different teams that may be a part of the virtual football match, at a depth value that is greater than minimum depth value for the L_1. A third spherical layer (L_3) may project a rain animation graphic around the virtual audience at a depth value that is greater than that of L_1 and L_2. A fourth spherical layer (L_4) may project English subtitles for the virtual football match, at a depth value that is greater than that of L_1, L_2, and L_3. A fifth spherical layer (L_5) may project a play button for the virtual football match at a depth value that is greater than that of L_1, L_2, L_3, and L_4.

In accordance with an embodiment, the media renderer **216** may be further configured to render the plurality of concentric spherical layers **220**A to **220**N in each video fragment of the 360° VR video as a plurality of voxels. The plurality of voxels may be rendered in a volume that may be aligned with a view plane of the user. A depth of field may be further added to different layers of voxels by application of a technique based on volumetric texture rendering. The detailed operations associated with the volumetric texture rendering may be known to one skilled in the art and therefore, such details have been omitted from the disclosure for the sake of brevity.

In some embodiments, the media renderer **216** may be further configured to render an audio item for a concentric spherical layer of each video fragment of a decoded 360° VR video. The audio item may be rendered in accordance with a 3D audio position value for the audio item of the concentric spherical layer. The 3D audio position value may specify a direction of audio perception and a depth of audio perception for the audio item of different concentric spherical layers of the plurality of concentric spherical layers **220**A to **220**N. The direction of audio perception may be further set in accordance with a gaze of the user **110** at a specific point on the plurality of concentric spherical layers **220**A to **220**N. For example, if the user **110** may look at a virtual audience that sits to the left of a virtual stadium, the direction of audio perception may be set from the audience sitting to the left of the stadium and the depth of audio perception may be set as per a depth value of the layer that includes the audience (as illustrated in FIG. **4**B).

At a time instant, the user **110** may intend to modify different attributes associated with different layers of content displayed at the VR display **202** of the VR device **102**. Thus, the processor **212** may receive a plurality of user inputs that may depict a preference of the user **110** for a type of immersive VR experience that may be of interest to the user **110**. The plurality of user inputs may be associated with a modification of a set of attributes in the image metadata associated with user-selected concentric spherical layers of the plurality of concentric spherical layers **220**A to **220**N in each video fragment of the rendered 360° VR video.

The plurality of user inputs may include, but are not limited to, a touch input, a haptic input, a gesture input, a voice input, a head-rotation input, or an eye movement input, and a pupil dilation input. Such user inputs may be collected based on different sensors that measure different features of the user **110**. Thus, in some embodiments, the processor **212** may be configured to collect user information from the plurality of sensors **208**. The user information may include data associated with a motion of the body and/or different body parts, movement of eyes of the user **110**, pupil contraction and dilation, gesture, touch, posture, facial expressions (for example, fear, sadness, happiness, apathy, anger, etc.), voice patterns, sentiments, and tone, and the like. For example, a MEMS-gyroscope in an HMD-based VR device may determine a change in the field-of-view of the 360° VR video based on movement of the head by 30° to the left along a yaw axis. Additionally, the processor **212** may be configured to collect data associated ambient parameters from the plurality of sensors **208**. The data associated with the ambient parameters may include luminance distribution in the environment that is ambient to the user **110**, an estimated occupancy in the ambient environment, a noise effect in the ambient environment, a type of built environment in use by the VR device **102**, an effective 3D map of the space available in the ambient environment, and the like.

The processor **212** may be further configured to generate a modified image metadata for each of the user-selected concentric spherical layers in each video fragment of the rendered 360° VR video. The modified image metadata may be generated based on modification of the set of attributes of the image metadata associated with the user-selected concentric spherical layers in each video fragment of the rendered 360° VR video. For example, the modified image metadata may include modifications in a layer type, layer content, a layer transparency, a depth value for the layer, an audio depth value for the layer, and the like. In some embodiments, the user **110** may touch and select different rendered concentric spherical layers in the virtual environment and modify the set of attributes in the image metadata for different concentric spherical layers. The modification of the set of attributes of the image metadata for the user-selected concentric spherical layers of different video fragments may correspond to a modification of the user-selected concentric spherical layers of different video fragments during the playback of the decoded 360° VR video at the VR display **202** of the VR device **102**.

The modified image metadata may be further utilized to personalize the immersive VR experience associated with the modifications in the rendered 360° VR video for the user **110**. Thus, the playback controller **218** may be configured to control playback of each video fragment rendered as the plurality of concentric spherical layers **220**A to **220**N. The controlled playback of each video fragment may correspond to at least one of a switch in a position, a modification of content, a modification of an audio depth perception, a direction of audio perception, or a level of transparency of different concentric spherical layers of each video fragment in the rendered 360° VR video. The playback may be controlled in accordance with the modified image metadata for the user-selected concentric spherical layers of each video fragment of the rendered 360° VR video. The playback of each video fragment may be further controlled based on user selection of the set of attributes in the image metadata of the user-selected concentric spherical layers of different video fragments. Thus, advantageously, the user **110** may interact with different concentric spherical layers of 360° VR video and personalize the playback of different portions of the 360° VR video during the real time or near real time playback of the 360° VR video. The interactivity, the engagement of the user **110** with different concentric spherical layers of the 360° VR video, and the controlled playback of the 360° VR video may be seamless with the real time or the near real time modifications in the image metadata for different concentric spherical layers of the 360° VR video.

In accordance with an embodiment, the playback controller **218** may be configured to switch a position of different concentric spherical layers of each video fragment of the rendered 360° VR video in accordance with a modification of a depth value for the different concentric spherical layers in the associated image metadata. The switch may be done based on a receipt of a user input for the modification of the depth value for the different concentric spherical layers. As an example, the user **110** may modify a depth value of the background spherical layer **220**N from "R1" to "R2" based on a touch or a swipe of the background spherical layer **220**N. In such implementations, the memory **210** may store multiple equirectangular image frames for a single image frame captured with different focal length values (represented by different f-numbers, i.e. a ratio (f/D) of a focal length (f) to a lens aperture diameter (D) for an imaging device). Therefore, the playback controller **218** may render the background spherical layer **220**N with an equirectangular image frame that is associated with a depth value **222**N selected by the user **110**. As an example, a background image (i.e., the outermost spherical layer with respect to a user's viewpoint) may be rendered at different depth values (e.g., as may be represented by an f-number "f/11") from a previous depth value (e.g., as may be represented by an f-number "f/8"). The modification from "f/8" to "f/11" may further increase a depth of field in content displayed in the background image.

The playback controller **218** may be further configured to modify content of different concentric spherical layers of each video fragment of the rendered 360° VR video. Such modification may be done in accordance with a modification of a layer type in the image metadata for the different concentric spherical layers. Examples of the layer type may include, but are not limited to, graphic images, textual content, interactive buttons, user interfaces, 3D depth textures, CGIs, or animation sequences. The modification may be further done based on the receipt of a user input for the modification of the layer type for the different concentric spherical layers. For example, the user **110** may provide a first input to modify the layer type of the inner most spherical layer (lowest depth of field from the user viewpoint **224**) from a button type to a subtitle type. Accordingly, the layer type of adjacent spherical layer may be modified from the animation type to button type. In general, the user **110** may decide which type of layer will have what type of depth of field with respect to the user viewpoint **224**.

In accordance with an embodiment, the playback controller may be configured to modify a depth of audio perception and a direction of audio perception of different audio items for different concentric spherical layers of each video fragment. The modification of the depth of audio perception and the direction of audio perception of different audio items may be done in accordance with a modification of a 3D audio position value for the different concentric spherical layers of each video fragment of the rendered 360° VR video. The modification of the depth of audio perception and the direction of audio perception of different audio items may be done further based on the receipt of a user input for the modification of the 3D audio position value for the different concentric spherical layers.

As an example, a position of the background spherical layer **220**N may be switched by the user by a modification of a depth value from "R_N" to "R_{N-3}" (i.e., a decrease in radius of concentric spherical layer). Thus, the audio item (for example, audience cheer) associated with background layer may further require a modification in the depth of audio perception, which may be proportional to the modification of the depth value associated with the change in position of the background spherical layer **220**N.

As another example, a user that wears an HMD VR device may move their head along either a yaw axis, a roll axis, or a pitch axis while getting engaged in a virtual football match. Such movements may cause a change in a virtual scene in the field of view of the user **110** and thus, the position of audience in a virtual stadium may change in the field of view. The playback controller **218** may be configured to modify the direction of audio depth perception with the playback of the audio item for the audience cheer. The modification in the direction of audio perception and the depth of audio perception may be done in accordance with collected user information associated with at least one of position of ears, noise in ambient environment, frequency sensitivity/audio amplitude sensitivity of the user, and the like. In some implementations, the depth of audio perception and the direction of audio perception of different audio items for different concentric spherical layers of each video fragment may be modified further based on a change in a point of gaze of the user **110** on the different concentric spherical layers of each video fragment at the VR display **202**. Such change in the point of gaze may be determined in accordance with a movement of user's eyes. In some cases, an eye movement sensor (or an image sensor) may be utilized to determine a change in a gaze of the user **110** at from one point to another point on different concentric spherical layers displayed at the VR device **102**.

In accordance with an embodiment, the playback controller **218** may be further configured to modify a level of transparency of different concentric spherical layers of each video fragment of the rendered 360° VR video. Such modifications in the level of transparency may be done in accordance with a modification of an alpha value of the different concentric spherical layers. The modification may be done further based on the receipt of a user input for the modification of the alpha value for the different concentric spherical layers. For example, an alpha value of "0.1" (or 10%) may be selected by a user for an inner most concentric spherical item layer for subtitles and an alpha value of "0.8" for a concentric spherical item layer of overlay graphic that is placed adjacent to the background spherical layer. Such modifications in the alpha value may be further utilized to hide or show a specific layer that is concentric to other layers that exhibit a depth of field that is greater than that of the specific layer. As per a default condition, the alpha value for a concentric spherical layer that has a lower depth value may be always kept below an alpha value for a concentric spherical layer that has a higher depth value. The default condition may be set as unmodifiable for a user to prevent a misconfiguration in visualization of the plurality of concentric spherical layers. Such misconfiguration in visualization may be caused by a decrease in a transparency of a concentric spherical layer that is rendered closer to a user's viewpoint with respect to a transparency level of a concentric spherical layer that is render away from the user's viewpoint at higher depth values.

In accordance with an embodiment, the rendered 360° VR video may be further personalized for the user **110**, by the processor **212**, based on a selective removal of different concentric layers from the rendered 360° VR video, a combination or a merger of two different concentric layers to a single concentric layer, a division of a single concentric layer to multiple concentric layers that may be rendered at different depth values, a modification of text, hyperlinks, other associated content or an appearance of a user interface, and the like.

The plurality of flat layers may be rendered as the plurality of concentric spherical layers **220**A to **220**N, i.e. from an equirectangular projection to a spherical projection. However, the spherical projection of the plurality of concentric spherical layers **220**A to **220**N may be viewed by the user as a rectilinear (or Gnomonic) projection of the same concentric spherical layers, without deviation from scope of the disclosure. Alternatively stated, the user **110** may view the concentric spherical images similar to how the user **110** usually perceives a scene, within a restricted field of view, for example, approximately "114°".

FIG. **2**C is an exemplary scenario that illustrates different rendered layers of 360° VR video at an HMD device, in accordance with another embodiment of the disclosure. FIG. **2**C is explained in conjunction with elements from FIGS. **1**, **2**A, and **2**B. With reference to FIG. **2**C, there is shown an exemplary scenario **200**C, where a set of concentric spherical layers (represented by L_1, L_2, L_3, L_4, and L_5) are rendered at different depth values (each depth value represents a radius of a concentric spherical layer) with respect to a user's viewpoint.

The set of concentric spherical layers (represented by L_1, L_2, L_3, L_4, and L_5) may include a first concentric spherical layer (L_1), a second concentric spherical layer (L_2), a third concentric spherical layer (L_3), a fourth concentric spherical layer (L_4), and a fifth concentric spherical layer (L_5). The set of concentric spherical layers (represented by L_1, L_2, L_3, L_4, and L_5) may be associated with a set of radius values (represented by R_1, R_2, R_3, R_4, and R_5) that may increase from R_1 to R_5 linearly. The depth of field may be different from a layer depth for a concentric spherical layer. The depth of field may refer to a resolution of content displayed in a concentric spherical layer in a longitudinal plane. The depth of field may be represented by a distance from a nearest object plane in focus to a farthest object plane that may be concurrently in focus in different concentric spherical layers, whereas the layer depth may represent a radius of each concentric spherical layer with respect to user's viewpoint. In some embodiments, the depth of field for each concentric spherical layer may be controlled, by the VR device **102**, based on a change in an f-number or a focal length of an imaging device that captures an image rendered as a spherical concentric layer. The f-number is represented by N, which is also represented as a ratio "f/D", where "f" is the focal length of the lens used by an imaging device, and "D" is a diameter of lens aperture exposed to light. The depth of field (D_F) may be represented by the equation (1).

The depth value for the first concentric spherical layer (L_1) may be less than a depth value for the second spherical layer (L_2) and so on. The content rendered at each spherical layer may be based on the image metadata specified for a flat layer in the decoded 360° video in the memory **210** of the VR device **102**. The image metadata for the first spherical layer (L_1) may specify a layer type as interactive buttons, with an f-number of **112**", where f represents the focal length and "2" represents a diameter of lens aperture, a depth value for L_1 represented by a radius R_1, an alpha value of "0.1", and the like. The image metadata for the second spherical layer (L_2) may specify a layer type as subtitles, an f-number of "f/2.5", a depth value for L_2 represented by a radius R_2, an alpha value of "0.2", and the like. The image metadata for the third spherical layer ("L_3") may specify a layer type as animation, an f-number of **114**", a depth value for L_3 represented by a radius R_3, an alpha value of "0.3", and the like. The image metadata for the fourth spherical layer (L_1) may specify a layer type as an overlay graphic, an f-number of "f/5.6", an alpha value of "0.4", and the like. The image metadata for the fifth spherical layer (L_5) may specify a layer type as a background image, an f-number of **118**", an alpha value of "0.5", and the like. The media renderer **216** may be configured to render a set of flat layers as the set of concentric spherical layers (represented by L_1, L_2, L_3, L_4, and L_5), at the VR display **202**, based on the attributes specified for each of the set of concentric spherical layers (represented by L_1, L_2, L_3, L_4, and L_5).

FIG. **3**A is an exemplary scenario that illustrates a video format of the 360° VR video that is rendered at the VR device, in accordance with an embodiment of the disclosure. FIG. **3**A is described in conjunction with elements from FIG. **1**, FIG. **2**A and FIG. **2**B. With reference to FIG. **3**A, there is shown a first scenario **300**A that is associated with rendering of an encoded 360° VR video **302** at an HMD device **304** worn by a user **306**.

The HMD device **304** stores the encoded 360° VR video **302** in the memory **210**. The encoded 360° VR video **302** may include a sequence of video fragments **308**A . . . **308**N. Each video fragment in the sequence of video fragments **308**A . . . **308**N may further include a plurality of flat layers, for example, a plurality of flat layers **310**A . . . **310**N in the video fragment **308**A. Alternatively stated, the encoded 360° VR video **302** may cluster a background image frame and associated layers that may be rendered concentric to the background image frame into a single video fragment. Different background frames may be clustered into different video fragments that may be stored in a sequence in the memory **210**.

A flat layer **310** in the plurality of flat layers **310**A . . . **310**N may be an equirectangular image frame **312**A that is associated with an image metadata **312**B. The image metadata **312**B may describe a set of attributes **314**A . . . **314**N associated with content, and different properties of the equirectangular image frame **312**A. For example, the set of attributes **314**A . . . **314**N may include a first attribute (M**1**) **314**A, a second attribute (M**2**) **314**B, a third attribute (M**3**) **314**C, a fourth attribute (M**4**) **314**D, and a fifth attribute (M**5**) **314**E. Such attributes M**1**, M**2**, M**3**, M**4**, and M**5** may be associated with at least one of a layer type (textual, background, user interface, button, animation, etc.), a depth value, an alpha value, a depth and direction of audio perception, and the like.

The encoded 360° VR video **302** may be decoded and rendered at the HMD device **304**. At a specific timeframe, a rendered 360° VR video **316** may include a plurality of concentric spherical layers (for example, a plurality of concentric spherical layers **318**A . . . **314**E) rendered from the plurality of flat layers **310**A . . . **310**N in the video fragment **308**A. Each layer of the plurality of concentric spherical layers **318**A . . . **318**E may provide a different depth of field to the user **306** with respect to the user viewpoint for example, a center of the plurality of concentric spherical layers **318**A . . . **318**N of the rendered 360° VR video **316**. The rendered 360° VR video **316** may further provide an immersive VR experience that may be further personalized by the user **306** based on different types of user inputs, for example, layer switching, depth adjustment, audio depth modification, transparency adjustments, layer hide/show, and the like.

FIG. **3**B is an exemplary scenario that illustrates a view of different rendered layers of 360° VR video at an HMD device worn by a user, in accordance with an embodiment of the disclosure. FIG. **3**B is explained in conjunction with elements from FIGS. **1**, **2**A, **2**B, and **3**A. With reference to FIG. **3**B, there is shown a second exemplary scenario **300**B that include a view of a plurality of concentric spherical layers **318**A . . . **318**E rendered at the HMD device **304** with respect to the user **306**. The view of the plurality of concentric spherical layers **318**A . . . **318**E may include a first layer **318**A, a second layer **318**B, a third layer **318**C, a fourth layer **318**D, and a fifth layer **318**E that are rendered at different depth of field at the HMD device **304** with respect to the user viewpoint.

The first layer **318**A may be an item layer that shows interactive buttons (for example, a play button to start the VR football match). The second layer **318**B may be another item layer that shows textual content (for example, subtitles for match commentary during the VR football match). The third layer **318**C may be yet another item layer that shows an overlay graphic (for example, competing players in a VR football match) at a depth of field different from that of the first layer **318**A and the second layer **318**B. The fourth layer **318**D may be an item layer that shows an animation effect (for example, rain effect over virtual audience in the VR football stadium) at a specific depth of field with respect to the user viewpoint. Finally, the fifth layer **318**E may be a background layer that shows a background image frame (for example, a VR football stadium) of a user requested VR content.

The HMD device **304** may be configured to measure different movements of the body parts of the user **306** as triggers for different interactive options associated with controlled playback of the rendered 360° VR video **316**. For example, head movements of the user **306** along a yaw axis **320**A, a roll axis **320**B, and a pitch axis **320**C may be utilized to pan around and zoom in/out to different portions of the rendered 360° VR video **316** within a field-of-view of the user **306**.

FIG. **4**A is an exemplary scenario that illustrates a modification of a depth of field of a background layer in response to a user input, in accordance with an embodiment of the disclosure. FIG. **4**A is explained in conjunction with elements from FIGS. **1**, **2**A, **2**B, **3**A, and **3**B. With reference to FIG. **4**A, there is shown a first scenario **400**A associated with modification of a depth value of the fifth layer **318**E (background image) in response to an input from the user **306**.

The I/O interface **206** of the HMD device **304** may receive a user input to modify a depth value of the fifth layer **318**E. The user input may be received (or detected) based on a body movement, an eye movement, a touch, or an external I/O console that may be controlled by the user **306**. The fifth layer **318**E may be rendered at a first depth value **402**, a second depth value **404**, a third depth value **406**, a fourth depth value **408**, and a fifth depth value **410**, based on a user input to switch the fifth layer from a first position to a second position in the concentric layers.

The equirectangular image frame in the fifth layer **318**E may be captured at different focal length values of an imaging device, for example, as represented by different f-numbers. For example, the fifth layer **318**E at the first depth value **402**, the second depth value **404**, the third depth value **406**, the fourth depth value **408**, and the fifth depth value **410**, may be associated with an f-number of "f/2", f/2.8", "f/4", "f/5.6", and "f/8". Here, "f" may be the focal length of the camera or the lens that captured the image frame of a scene via an image sensor and 2, 2.8, 4, 5.6, and 8 may represent f-numbers that also represents an f-stop.

FIG. **4**B is an exemplary scenario that illustrates a modification of a depth of audio perception and a direction of audio perception for different rendered layers in response to a user input, in accordance with an embodiment of the disclosure. FIG. **4**B is explained in conjunction with elements from FIGS. **1**, **2**A, **2**B, **3**A, **3**B, and **4**A. With reference to FIG. **4**B, there is shown a second scenario **400**B associated with modification of a direction and depth of audio perception of a layer in the plurality of concentric spherical layers **318**A . . . **318**E of the video fragment **308**A, in response to an input from the user **306**.

In some cases, an input may be provided by the user **306** to the HMD device **304**. Such input may be a touch input or a console input for selection of a region-of-focus **412** on the one of the plurality of concentric spherical layers **318**A . . . **318**E rendered at the HMD device **304**. The HMD device **304** may utilize the region-of-focus **412** to set a direction of audio perception and a depth of audio perception with respect to ears of the user. Alternatively stated, the HMD device **304** may determine direction vectors **414** that points from the region-of-focus **412** to the both the ears of the user **306** to provide an immersive and directional audio perception to the user **306**. The HMD device **304** may adjust an audio depth value for an audio item specified for that layer such that the rendered audio is directed from the region-of-focus **412** to the ears of the user **306**.

In other cases, the user **306** may gaze at a specific point on one of the layers rendered at the HMD device **304**. The HMD device **304** may be configured to identify a look direction (shown by direction vectors **414**) and the region-of-focus **412** based on point of gaze with respect to the view plane of the user **306**. The HMD device **304** may further render an audio item for the layer such that the direction of audio perception and the depth of audio perception is perceived by the user **306** as directed from the region-of-focus **412**.

FIG. **5** is a flow chart that illustrates an exemplary method for user-interactive playback of immersive VR video, in accordance with an embodiment of the disclosure. FIG. **5** is explained in conjunction with elements from FIGS. **1**, **2**, **3**A-**3**B, and **4**A-**4**C. With reference to FIG. **5**, there is shown a flowchart **500**. The method starts at **502** and proceeds to step **504**.

At **504**, an encoded 360° VR video may be stored at the VR device **102**. The memory **210** may be configured to store the encoded 360° VR video at the VR device **102**. The encoded 360° VR video may include a sequence of video fragments. Each video fragment may include a plurality of flat layers. Each flat layer of the plurality of flat layers may be an equirectangular image frame that may be associated with an image metadata.

At **506**, a decoded 360° VR video may be generated by decompression of the plurality of flat layers and the image metadata for each flat layer of the encoded video fragment of the encoded 360° VR video. The media decoder **214** may be configured to generate the decoded 360° VR video by decompression of the plurality of flat layers and the image metadata for each flat layer of the encoded video fragment of the encoded 360° VR video.

At **508**, the plurality of flat layers in each video fragment of the encoded 360° VR video may be rendered as a plurality of concentric spherical layers projected at the VR display **202** at a plurality of depth values with respect to a user viewpoint, based on the image metadata for each flat layer of the plurality of flat layers. The media renderer **216** may be configured to render the plurality of flat layers in each video fragment of the encoded 360° VR video as a plurality of concentric spherical layers projected at the VR display **202** at a plurality of depth values with respect to a user viewpoint. The plurality of flat layers in each video fragment of the encoded 360° VR video may be rendered as a plurality of concentric spherical layers, based on the image metadata for each flat layer of the plurality of flat layers.

At **510**, an audio item may be rendered for a concentric spherical layer of each video fragment of the rendered 360 video, in accordance with a 3D audio position value for the audio item in the concentric spherical layer. The media renderer **216** may be configured to render an audio item for a concentric spherical layer of each video fragment of the rendered 360 video, in accordance with a 3D audio position value for the audio item in the concentric spherical layer.

At **512**, a plurality of user inputs that may be associated with a modification of a set of attributes in the image metadata of at least one concentric spherical layer in each video fragment of the rendered 360° VR video may be received. The processor **212** may be configured to receive a plurality of user inputs that may be associated with a modification of a set of attributes in the image metadata of at least one concentric spherical layer in each video fragment of the rendered 360° VR video.

At **514**, a modified image metadata may be generated for the at least one concentric spherical layer of the plurality of concentric spherical layers of the video fragment of the rendered 360° VR video, based on modification of the set of attributes of the image metadata associated with the at least one concentric spherical layer of the video fragment. The processor **212** may be configured to generate a modified image metadata for the at least one concentric spherical layer of the plurality of concentric spherical layers of the video fragment of the rendered 360° VR video. The modified image metadata may be generated based on modification of the set of attributes of the image metadata associated with the at least one concentric spherical layer of the video fragment.

At **516**, playback of each video fragment rendered as the plurality of concentric spherical layers may be controlled in accordance with the modified image metadata for the at least one concentric spherical layer of each video fragment of the rendered 360° VR video. The playback controller **218** may be configured to control playback of each video fragment rendered as the plurality of concentric spherical layers in accordance with the modified image metadata for the at least one concentric spherical layer of each video fragment of the rendered 360° VR video. Control passes to end.

Various embodiments of the disclosure may provide a non-transitory computer readable medium and/or storage medium, and/or a non-transitory machine readable medium and/or storage medium with a machine code and/or a set of instructions stored thereon and executable by a machine and/or a computer for VR media content generation in a multi-layer structure and interactive playback of the generated VR media content in the multi-layer structure. The set of instructions in the VR device **102** may cause the machine and/or computer to perform the steps for a user-interactive playback of immersive VR content with an adjustable depth of field. The VR device **102** may include the VR playback circuitry **200**, the VR display **202**, and the memory **210**. The memory **210** may be configured to store an encoded 360° VR video that may include a sequence of video fragments. Each video fragment may include a plurality of flat layers and each flat layer of the plurality of flat layers may be at least one equirectangular image frame that is associated with an image metadata. The VR playback circuitry **200** may be configured to render the plurality of flat layers in each video fragment of the encoded 360° VR video as a plurality of concentric spherical layers projected at the VR display at a plurality of depth values with respect to a user viewpoint. The plurality of flat layers may be rendered as the plurality of concentric spherical layers, based on the image metadata for each flat layer of the plurality of flat layers. The VR playback circuitry **200** may be further configured to receive a plurality of user inputs associated with a modification of a set of attributes in the image metadata. The plurality of user inputs for the modification of the set of attributes in the image metadata may be associated with at least one concentric spherical layer of the plurality of concentric spherical layers in each video fragment of the rendered 360° VR video. The VR playback circuitry **200** may be configured to generate a modified image metadata for the at least one concentric spherical layer of the plurality of concentric spherical layers of the video fragment of the rendered 360° VR video. The modified image metadata may be generated based on modification of the set of attributes of the image metadata associated with the at least one concentric spherical layer of the video fragment. The VR playback circuitry **200** may be further configured to control playback of each video fragment rendered as the plurality of concentric spherical layers in accordance with the modified image metadata for the at least one concentric spherical layer of each video fragment of the rendered 360° VR video. The playback of each video fragment may be controlled based on user selection of the set of attributes in the image metadata associated with the at least one concentric spherical layer of the video fragment.

Various embodiments of the present disclosure may be found in a method and a VR device for a user-interactive playback of immersive VR content with an adjustable depth of field. The VR device may include a VR display, a memory, and a VR playback circuitry. The memory may be configured to store an encoded 360° VR video that may include a sequence of video fragments. Each video fragment may include a plurality of flat layers and each flat layer of the plurality of flat layers may be at least one equirectangular image frame that is associated with an image metadata. The VR playback circuitry is configured to render the plurality of flat layers in each video fragment of the encoded 360° VR video as a plurality of concentric spherical layers projected at the VR display at a plurality of depth values with respect to a user viewpoint. The plurality of flat layers may be rendered as the plurality of concentric spherical layers, based on the image metadata for each flat layer of the plurality of flat layers. The VR playback circuitry may be further configured to receive a plurality of user inputs associated with a modification of a set of attributes in the image metadata. The plurality of user inputs for the modification of the set of attributes in the image metadata may be associated with at least one concentric spherical layer of the plurality of concentric spherical layers in each video fragment of the rendered 360° VR video. The VR playback circuitry may be configured to generate a modified image metadata for the at least one concentric spherical layer of the plurality of concentric spherical layers of the video fragment of the rendered 360° VR video. The modified image metadata may be generated based on modification of the set of attributes of the image metadata associated with the at least one concentric spherical layer of the video fragment. The VR playback circuitry may be further configured to control playback of each video fragment rendered as the plurality of concentric spherical layers in accordance with the modified image metadata for the at least one concentric spherical layer of each video fragment of the rendered 360° VR video. The playback of each video fragment may be controlled based on user selection of the set of attributes in the image metadata associated with the at least one concentric spherical layer of the video fragment.

In accordance with an embodiment, the VR playback circuitry may be configured to generate a decoded 360° VR video by decompression of the plurality of flat layers and the image metadata for each flat layer of the encoded video fragment of the encoded 360° VR video. The set of attributes in the image metadata for each flat layer may include layer information associated with a layer type, a depth value, a three dimensional (3D) audio position value, an alpha value, and media player-specific information, which may be utilized to render each flat layer as a concentric spherical layer.

In accordance with an embodiment, the plurality of concentric spherical layers may include a background spherical layer and a plurality of spherical item layers. The VR playback circuitry may be further configured to render the background spherical layer as an outermost concentric spherical layer of the plurality of concentric spherical layers. The background spherical layer may be associated with a depth value that is a maximum of the plurality of depth values specified for the plurality of flat layers in each video fragment of a decoded 360° VR video. Similarly, the VR playback circuitry may be further configured to render each of the plurality of spherical item layers as an inner concentric spherical layer of the plurality of concentric spherical layers. The plurality of spherical item layers may include at least one of a graphic image, textual content, an interactive button, a user interface, a 3D depth texture, a computer-generated imagery (CGI), or an animation sequence. A depth value for each flat layer of each video fragment may correspond to a radius of a concentric spherical layer measured with respect to the user viewpoint.

In accordance with an embodiment, the VR playback circuitry may be further configured to render an audio item for a concentric spherical layer of each video fragment of the rendered 360° VR video, in accordance with a 3D audio position value for the audio item of the concentric spherical layer. The plurality of user inputs may include at least one of a touch input, a haptic input, a gesture input, a voice input, a head-rotation input, or an eye movement input, and a pupil dilation input.

In accordance with an embodiment, the modification of the set of attributes of the image metadata for the at least one concentric spherical layer of the video fragment may correspond to a modification of the at least one concentric spherical layer of the video fragment during the playback of the rendered 360° VR video. The controlled playback of each video fragment in accordance with the modified image metadata may correspond to at least one of a switch in a position, a modification of content, a modification of an audio depth perception and a direction of audio perception, or a level of transparency of different concentric spherical layers of each video fragment in the rendered 360° VR video.

In accordance with an embodiment, the VR playback circuitry may be configured to switch a position of different concentric spherical layers of each video fragment of the rendered 360° VR video in accordance with a modification of a depth value for the different concentric spherical layers in the modified image metadata. The switch may be done based on the receipt of a user input for the modification of the depth value for the different concentric spherical layers. The VR playback circuitry may be further configured to modify content of different concentric spherical layers of each video fragment of the decoded 360° VR video in accordance with modification of a layer type in the image metadata for the different concentric spherical layers. The modification may be done based on the receipt of a user input for the modification of the layer type for the different concentric spherical layers.

In accordance with an embodiment, the VR playback circuitry may be further configured to modify an audio depth perception and a direction of audio perception of different audio items for different concentric spherical layers of each video fragment. The modification in the audio depth perception and the direction of audio perception may be done in accordance with a modification of a 3D audio position value for the different concentric spherical layers of each video fragment of a decoded 360° VR video. The modification is based on the receipt of a user input for the modification of the 3D audio position value for the different concentric spherical layers. The audio depth perception and the direction of audio perception of different audio items for different concentric spherical layers of each video fragment is modified further based on a change in a point of gaze of the user on the different concentric spherical layers of each video fragment at the VR display, in accordance with a movement of eyes of the user.

In accordance with an embodiment, the VR playback circuitry may be further configured to modify a level of transparency of different concentric spherical layers of each video fragment of the rendered 360° VR video. Such modification may be done in accordance with a modification of an alpha value of the different concentric spherical layers. The modification may be done based on the receipt of a user input for the modification of the alpha value for the different concentric spherical layers.

In accordance with an embodiment, the VR playback circuitry may be further configured to render the plurality of concentric spherical layers in each video fragment of the 360° VR video as a plurality of voxels in a volume aligned with a view plane of the user. A depth of field may be further added to the plurality of voxels by application of a technique based on volumetric texture rendering.

The present disclosure may be realized in hardware, or a combination of hardware and software. The present disclosure may be realized in a centralized fashion, in at least one computer system, or in a distributed fashion, where different elements may be spread across several interconnected computer systems. A computer system or other apparatus adapted for carrying out the methods described herein may be suited. A combination of hardware and software may be a general-purpose computer system with a computer program that, when loaded and executed, may control the computer system such that it carries out the methods described herein. The present disclosure may be realized in hardware that comprises a portion of an integrated circuit that also performs other functions.

The present disclosure may also be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which when loaded in a computer system is able to carry out these methods. Computer program, in the present context, means any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly, or after either or both of the following: a) conversion to another language, code or notation; b) reproduction in a different material form.

While the present disclosure has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed, but that the present disclosure will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A virtual reality (VR) device, comprising:

a VR display;

a memory configured to store an encoded 360° VR video that comprises a sequence of video fragments,

wherein each video fragment of the sequence of video fragments comprises a plurality of flat layers, and

wherein each flat layer of the plurality of flat layers is at least one equirectangular image frame associated with an image metadata; and

VR playback circuitry, wherein the VR playback circuitry is configured to:

render the plurality of flat layers in each video fragment of the encoded 360° VR video as a plurality of concentric spherical layers projected at the VR display at a plurality of depth values with respect to a user viewpoint, based on the image metadata for each flat layer of the plurality of flat layers;

receive a plurality of user inputs associated with a modification of a set of attributes in the image metadata associated with at least one concentric spherical layer of the plurality of concentric spherical layers in each video fragment of the rendered 360° VR video;

generate a modified image metadata for the at least one concentric spherical layer of the plurality of concentric spherical layers of the video fragment of the rendered 360° VR video, based on modification of the set of attributes of the image metadata associated with the at least one concentric spherical layer of the video fragment; and

control playback of each video fragment rendered as the plurality of concentric spherical layers in accordance with the modified image metadata for the at least one concentric spherical layer of each video fragment of the rendered 360° VR video, wherein the playback of each video fragment is controlled based on user selection of the set of attributes in the image metadata associated with the at least one concentric spherical layer of the video fragment.

2. The VR device according to claim **1**, wherein the VR playback circuitry is further configured to generate a decoded 360° VR video by decompression of the plurality of flat layers and the image metadata for each flat layer of the encoded video fragment of the encoded 360° VR video.

3. The VR device according to claim **1**, wherein the set of attributes in the image metadata for each flat layer comprises layer information associated with a layer type, a depth value, a three dimensional (3D) audio position value, an alpha value, and media player-specific information, which is utilized to render each flat layer as a concentric spherical layer.

4. The VR device according to claim **1**, wherein the plurality of concentric spherical layers comprises a background spherical layer and a plurality of spherical item layers.

5. The VR device according to claim **4**, wherein the VR playback circuitry is further configured to render the background spherical layer as an outermost concentric spherical layer of the plurality of concentric spherical layers.

6. The VR device according to claim **5**, wherein the background spherical layer is associated with a depth value that is a maximum of the plurality of depth values specified for the plurality of flat layers in each video fragment of a decoded 360° VR video.

7. The VR device according to claim **4**, wherein the VR playback circuitry is further configured to render each of the plurality of spherical item layers as an inner concentric spherical layer of the plurality of concentric spherical layers.

8. The VR device according to claim **7**, wherein the plurality of spherical item layers comprises at least one of a graphic image, textual content, an interactive button, a user interface, a 3D depth texture, a computer-generated imagery (CGI), or an animation sequence.

9. The VR device according to claim **1**, wherein a depth value for each flat layer of each video fragment corresponds to a radius of a concentric spherical layer measured with respect to the user viewpoint.

10. The VR device according to claim **1**, wherein the VR playback circuitry is further configured to render an audio item for a concentric spherical layer of each video fragment of the rendered 360° VR video, in accordance with a 3D audio position value for the audio item of the concentric spherical layer.

11. The VR device according to claim 1, wherein the plurality of user inputs comprises at least one of a touch input, a haptic input, a gesture input, a voice input, a head-rotation input, or an eye movement input, and a pupil dilation input.

12. The VR device according to claim 1, wherein the modification of the set of attributes of the image metadata for the at least one concentric spherical layer of the video fragment corresponds to a modification of the at least one concentric spherical layer of the video fragment during the playback of the rendered 360° VR video.

13. The VR device according to claim 1, wherein the VR playback circuitry is further configured to switch a position of different concentric spherical layers of each video fragment of the rendered 360° VR video in accordance with a modification of a depth value for the different concentric spherical layers in the modified image metadata, wherein the switch is based on the receipt of a user input for the modification of the depth value for the different concentric spherical layers.

14. The VR device according to claim 1, wherein the VR playback circuitry is further configured to modify content of different concentric spherical layers of each video fragment of the rendered 360° VR video in accordance with a modification of a layer type in the image metadata for the different concentric spherical layers, wherein the modification is based on the receipt of a user input for the modification of the layer type for the different concentric spherical layers.

15. The VR device according to claim 1, wherein the VR playback circuitry is further configured to modify a depth of audio perception and a direction of audio perception of different audio items for different concentric spherical layers of each video fragment, in accordance with a modification of a 3D audio position value for the different concentric spherical layers of each video fragment of the rendered 360° VR video, wherein the modification is based on the receipt of a user input for the modification of the 3D audio position value for the different concentric spherical layers.

16. The VR device according to claim 15, wherein the audio depth perception and the direction of audio perception of different audio items for different concentric spherical layers of each video fragment is modified further based on a change in a point of gaze of a user on the different concentric spherical layers of each video fragment at the VR display, in accordance with movement of eyes of the user.

17. The VR device according to claim 1, wherein the VR playback circuitry is further configured to modify a level of transparency of different concentric spherical layers of each video fragment of the rendered 360° VR video, in accordance with a modification of an alpha value of the different concentric spherical layers, and wherein the modification is based on the receipt of a user input for the modification of the alpha value for the different concentric spherical layers.

18. The VR device according to claim 1, wherein the controlled playback of each video fragment in accordance with the modified image metadata corresponds to at least one of a switch in a position, a modification of content, a modification of an audio depth perception and a direction of audio perception, or a level of transparency of different concentric spherical layers of each video fragment in the rendered 360° VR video.

19. The VR device according to claim 1, wherein the VR playback circuitry is further configured to render the plurality of concentric spherical layers in each video fragment of the 360° VR video as a plurality of voxels in a volume aligned with a view plane of a user, wherein a depth of field is added to the plurality of voxels by application of a technique based on volumetric texture rendering.

20. A method, comprising:

in a virtual reality (VR) device that comprises a VR display, a memory, and VR playback circuitry:

storing, in the memory, an encoded 360° VR video that comprises a sequence of video fragments, wherein each video fragment comprises a plurality of flat layers, wherein each flat layer of the plurality of flat layers is at least one equirectangular image frame associated with an image metadata

rendering, by the VR playback circuitry, the plurality of flat layers in each video fragment of a decoded 360° VR video as a plurality of concentric spherical layers projected at the VR display at a plurality of depth values with respect to a viewpoint of a user, based on the image metadata for each flat layer of the plurality of flat layers;

receiving, by the VR playback circuitry, a plurality of user inputs associated with a modification of a set of attributes in the image metadata associated with at least one concentric spherical layer of the plurality of concentric spherical layers in each video fragment of the rendered 360° VR video;

generating, by the VR playback circuitry, a modified image metadata for the at least one concentric spherical layer of the plurality of concentric spherical layers of the video fragment of the rendered 360° VR video, based on modification of the set of attributes of the image metadata associated with the at least one concentric spherical layer of the video fragment; and

controlling, by the VR playback circuitry, playback of each video fragment rendered as the plurality of concentric spherical layers in accordance with the modified image metadata for the at least one concentric spherical layer of each video fragment of the rendered 360° VR video, wherein the playback of each video fragment is controlled based on user selection of the set of attributes in the image metadata associated with the at least one concentric spherical layer of the video fragment.

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